CRANE ACCIDENTS IN THE SAUDI ARABIAN CONSTRUCTION INDUSTRY

BY

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A Thesis Presented to the

DEANSHIP OF GRADUATE STUDIES

KING FAHD UNIVERSITY OF PETROLEUM & MINERALS

DHAHRAN, SAUDI ARABIA

In Partial Fulfillment of the

Requirements for the Degree of

MASTER OF SCIENCE

In

CONSTRUCTION ENGINEERING AND MANAGEMENT

January 2017

KING FAHD UNIVERSITY OF PETROLEUM & MINERALS

DHAHRAN- 31261, SAUDI ARABIA

DEANSHIP OF GRADUATE STUDIES

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DEDICATION

Dedicated to my beloved parents, my mentors, who were always by my side and taught me to trust in Almighty Allah, believe in determination and hard work to accomplish anything.

Dedicated to my siblings, my dearest sisters, who gave me love, support and inspiration all along.

Dedicated to all those people who have lost their lives to accidents in the construction Industry and their families who had to suffer huge losses.

ACKNOWLEDGMENTS

In the name of ALLAH, the Most Gracious, the Most Merciful

Firstly, I thank Almighty Allah for guiding me in every stage of my life, especially in my Masters Education, all Gratitude and Appreciation belong to Him.

I thank my parents, whose love and favor I can never compensate.

I would like to extend my sincere gratitude to my thesis advisor, Dr. Sadi Assaf, for his unswerving guidance and support throughout my Masters. I also earnestly thank all my Professors, especially in my Thesis committee, Dr. Khalaf Al Ofi and Dr. Bambang T. Suhariadi for providing a valuable insight and assistance in my research.

I am grateful to my siblings, who sacrificed a lot in life to keep me going. No one can replace you both.

I also express heartful gratitude to all my friends who helped me in this research especially Khalid, Adnan, Tahir, Abdul Latif and Aamer.

Last but not the least for my brother in life, Yousuf, who has always been my emotional support and my best friend in Life. I supplicate to Allah to protect us all. Ameen.

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LIST OF ABBREVIATIONS

Saudi Aramco: Saudi Arabian Oil Company

MOMRA: Ministry of Municipal and Rural Affairs

ABSTRACT

Full Name : Basheeruddin Mohammed Fasiuddin

Thesis Title : Crane Accidents in the Saudi Arabian Construction Industry

Major Field : Construction Engineering and Management

Date of Degree : January 2017

This Research was conducted to address the problem of increasing accidents involving cranes. To better understand the problem, general aspects of safety were also studied like safety standards, Safety Training, etc. along with specific factors for Crane Safety. The objectives of the Research were (1) To analyze Incident data of the past 5 years (2) To understand Safety Standard Enforcement and Implementation at National Level (in Saudi Arabia) as well as at Company Level and; (3) To outline the Preventive Measures used for Cranes and their extent of effect in the Saudi Arabian Construction Industry. The objectives were accomplished analyzing the data obtained from personal interviews questionnaire survey conducted with the experienced professionals. Data was obtained by surveying around 55 contracting companies. The scope of the research was limited to Eastern Province and only Grade 1, 2 and 3 building Contractors were surveyed. It was found that Human factors related to safety and Management of the company are two subjects that should be given significant consideration to eliminate problems associated with the construction industry in K.S.A. Also highlighted was the fact that Client play a crucial role in implementing safety and to prevent accidents in the construction industry but there is no specific Ministry or Agency that enforces standards of safety over all in KSA. Further, it was observed preventive measures have very little effect on Crane Incident prevention.

ملخص الرسالة

الاسم الكامل: بشير الدين محمد فصيح الدين

عنوان الرسالة: الحوادث رافعة في صناعة البناء في المملكة العربية السعودية

التخصص: قسم الإدارة وهندسة التشييد

تاريخ الدرجة العلمية: يناير 2017

رافعات مهمة إلى موقع البناء، ومساعدتنا على بناء بوتيرة عالية جدا مع أقل جهد وأقصر وقت ممكن. وبما أن هذه الآلات هي كبيرة جدا وثقيلة، وأدنى سوء من ذلك يؤدي إلى خسائر فادحة في الأرواح والممتلكات ويسبب خسائر مالية ضخمة. أجريت هذه الأبحاث لمعالجة مشكلة حوادث الرافعات. تمت دراسة الجوانب العامة لسلامة أيضا مثل معايير السلامة، التدريب في مجال السلامة جنبا إلى جنب مع العوامل المحددة للسلامة الرافعات. وكانت أهداف البحث١ تحليل بيانات الحوادث في السنوات الخمس الماضية ٢ لفهم السلامة إنفاذ المعايير والتنفيذ على المستوى الوطني (في السعودية) وكذلك في مستوى الشركة ٣ لتسليط الضوء على التدابير الوقائية تستخدم لالرافعات ومداها من تأثير في صناعة البناء في المملكة العربية السعودية. تم إنجاز أهداف تحليل البيانات التي تم الحصول عليها من المسح المقابلات الشخصية استبيان أجري مع المهنيين ذوي الخبرة. تم الحصول على بيانات من مسح حول خمسة والخمسين شركات المقاولات . نطاق مؤلفاته كانت تقتصر على المنطقة الشرقية،للمقاولين بناء في الدرجة واحدة و اثنين وثلاثة . وقد وجد أن العوامل البشرية المتعلقة بالسلامة وإدارة الشركة هما الموضوعات التي وينبغي إيلاء الاعتبار للقضاء على المشاكل المرتبطة صناعة البناء والتشييد في المملكة العربية السعودية. وأيضا أوضح أن حقيقة أن العميل يكون لها دور حاسم في تنفيذ السلامة ومنع الحوادث في صناعة البناء والتشييد ولكن ليس هناك وزارة أو وكالة محددة تطبق معايير السلامة على كافة في المملكة العربية السعودية . لوحظ التدابير الوقائية لها تأثير ضئيل جدا على الوقاية الحوادث الرافعات

CHAPTER 1

INTRODUCTION

1.1 Background

When comparing with other industries, construction industry is associated with very high injuries and fatalities due to the complicated, dynamic and constantly shifting nature of work. One of the significant components for execution of construction work is cranes which is the reason for up to one-third of the deaths in the construction industry (Neitzel et al 2001). Crane being the most utilized and massive equipment in the construction industry can cause property destruction and fatalities. Hence crane operation requires a "well designed environment and high safety zone" (Zayed and Abbas 2013). Both mobile cranes and tower cranes are the backbone of construction industry all around the world, although former was used mainly in the US construction industry and later in the European construction industry. Nevertheless recently, tower cranes are being widely used due to many constraints encountered while using mobile crane while building high rise buildings. In any case, safety is a major concern when it comes to using cranes. (Shapira and Lyachin 2009)

Causes of crane accidents are varying through literature but Beavers et al (2006) listed the most frequent and mutually exclusive causes. They are: "Struck by load,

Electrocution, Crushed during Installation/Dismantling, Failure of boom, Crane tip over, struck by counterweight and falls". According to A.A. Marquez et al (2014), the most common reasons for crane accidents are due to harsh weather, structural deficiencies, foundation problems, overload and errors during installation and dismantling of cranes.

In addition to reduce the risk of crane accidents and improve safety, it is important to understand the system as whole on the construction site and not to look at cranes only. No doubt crane safety is mainly associated with cranes but safety won't be rightly implemented unless other elements that interact with crane are duly taken into consideration thus following an integrated approach.

Further, in the book "Cranes and Derricks" (2011), the authors mention the most common causes of crane accidents as follows:

"Defective Equipment, Pressure from cost or time constraints, Inexperienced Management, Lack of Training, knowledge or skill, Inadequate planning, Environmental Conditions, Operator errors and Changed Circumstances"

As we can see all reasons except the first involves the interaction of other elements with the crane potentially causing accidents. Hence it was rightly said "It comes down to skills, motivation and attention to detail of the people operating and caring for these machines that will determine their safety."

(Hakkinen 1993) (http//: failures.wikispaces.com)

The construction sector in Saudi Arabia is attracting construction companies from all over the world in various development projects all over the country. Also, 15% of the

total workforce is employed in the construction sector alone. Despite this, there is no government agency that regulates the construction safety activities in Saudi Arabia. A recent study by Berger (2008) on safety in Saudi Arabia across several construction projects shows that: “25% of contractors did not give new workers a safety orientation; 25% did not provide personal protective equipment; 25% did not provide first-aid on site and 38% had no trained safety personnel” which indicated that the safety concept is given less importance among construction contractors in Saudi Arabia. Besides, many construction companies don’t have the idea as to why the safety programs have little or no effect despite controlling accidents costs and lowering project delays caused by the accidents. (Haadir et al, 2011)

1.2 Problem Statement

“Safety in the context of Civil Engineering is defined as the discipline of preserving the health of those who build, operate, maintain and demolish engineering works and of others affected by those works”. In other words, construction accidents not only may endanger the lives of those are working in the site but all those around who may or may not be the part of ongoing or finished construction work. further, they cause major economic loss in terms of the following:

- “Damage to plant and Equipment
- Damage to work already completed
- Loss of productive work time
- Reduced work rate
- Legal costs, fines, compensation for victims, etc.

- Loss of confidence and reputation
- Increased insurance premiums”

(Construction Safety Handbook 1990)

Cranes causing majority of the construction accidents is evident from the past literature and everyday news. There are many research papers discussing the crane failures in different parts of the world, the most disastrous one being the Makkah crane collapse in September 2015. Other famous crane disasters include the Miller park crane accident in Wisconsin, USA, Bellevue tower crane collapse in Washington, USA, Rotterdam crane collapse, etc. Furthermore, accidents continue to happen even to this day even though studies were carried out and new regulations were imposed on construction sites using cranes.

There are records of minor accidents occurring in Saudi Arabia involving cranes like in Jubail, Jeddah, Makkah etc. but the latest crane accident left everyone tormented and disturbed. It became the deadliest crane accident ever killing 111 and leaving 394 people injured. Hence it is significant to investigate the current practices of crane use, its operation and management large scale to small scale projects and find out answers to the following questions: -

1. What is the rate of accidents in the Saudi Arabian Construction Industry involving cranes?
2. What are the common causes of crane accidents on construction sites?
3. What is the level of safety standards enforcement and implementation on construction sites?

4. What are the practices or preventive measures followed to an ensure safety environment at construction sites using cranes?
5. What is the extent of effect of the above prevention measures to prevent crane accidents?

1.3 Aim of the Research

AIM: “To gain insight on the accidents involving Cranes in the Saudi Arabian Construction Industry”

1.4 Objectives of the Research

The prime objectives are:

- To analyze Incident data of the past 5 years: to identify the prevalent causes and people affected in the Crane Incidents in the Saudi Arabian Construction Industry
- To understand Safety Standard Enforcement and Implementation at National Level (in Saudi Arabia) as well as at Company Level
- To outline the Preventive Measures used in the Saudi Arabian Construction Industry and their extent of effect on Accident Prevention involving Cranes

1.5 Significance of the Research

Taking into consideration the size and capability of mobile or tower cranes, improper planning or lack of safety procedures may result in loss of property and life. In general, both tower cranes and mobile cranes work concurrently to move materials in a characteristic commercial construction site. Any load mishandled can right away injure or kill workers and those around and potentially upset an important phase of the

construction project, conceivably causing partial or complete damage to the structure as well as the crane itself. (Neitzel et al 2001).

Despite being one of the fastest growing countries in the world, Saudi Arabia has the highest fatal and non-fatal major injuries. Moreover, practicing safety culture was still a big challenge, according to the results of a comparative study between eight developed and Arab countries. (Alasamri et al, 2012)

Therefore, this study will be helpful:

- To gain a general understanding of level of safety on Construction Sites regarding Cranes
- To understand how can crane safety be improved on a construction site
- To suggest changes to be incorporated at national level as well as company level that will assist the construction companies to prevent future crane accidents, which in turn will prevent loss of human lives, damage to property, economic losses etc. thus developing a safer society to live in

1.6 Scope and limitations of the Research

Due to Time and Budget constraints, this study was performed in the Eastern province of Saudi Arabia particularly in the cities Dammam, Khobar and Dhahran. Also, only Grade 1, Grade 2 and Grade 3 building contractors were included in the population as they were involved in major usage of Cranes.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

According to *Dictionary of Architecture and Construction*, Crane is defined as "A machine for lifting or lowering a load and moving it horizontally, in which the hoisting mechanism is an integral part of the machine; classified by mounting, by boom configuration, and by lifting capacity". Cranes are gigantic equipment used in the construction industry all over the world to move load vertically as well as horizontally which are beyond the human capability. (Harris, C. 2011)

2.2 Types of Cranes

There are basically two types of cranes, mobile crane and tower crane. The following figures (Figure 1 and Figure 2) show the two basic types of Cranes:

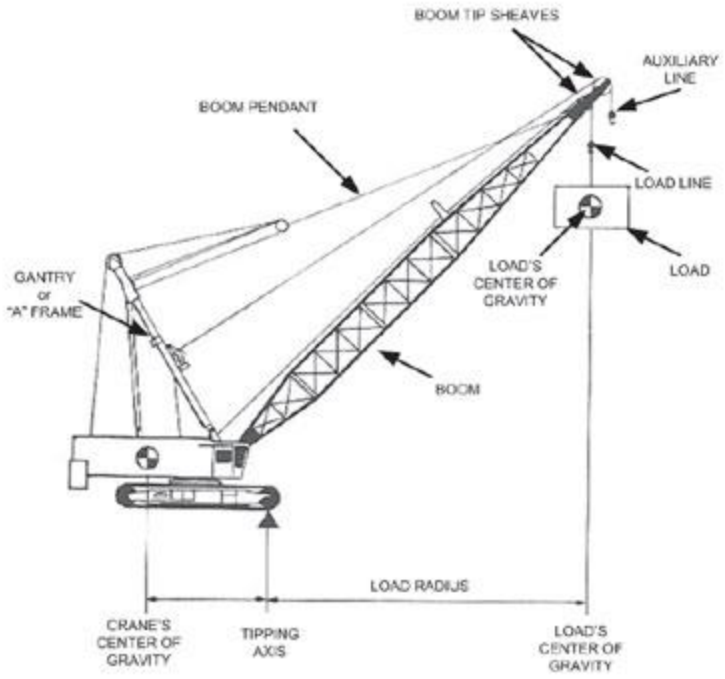

Figure 1: Mobile Crane

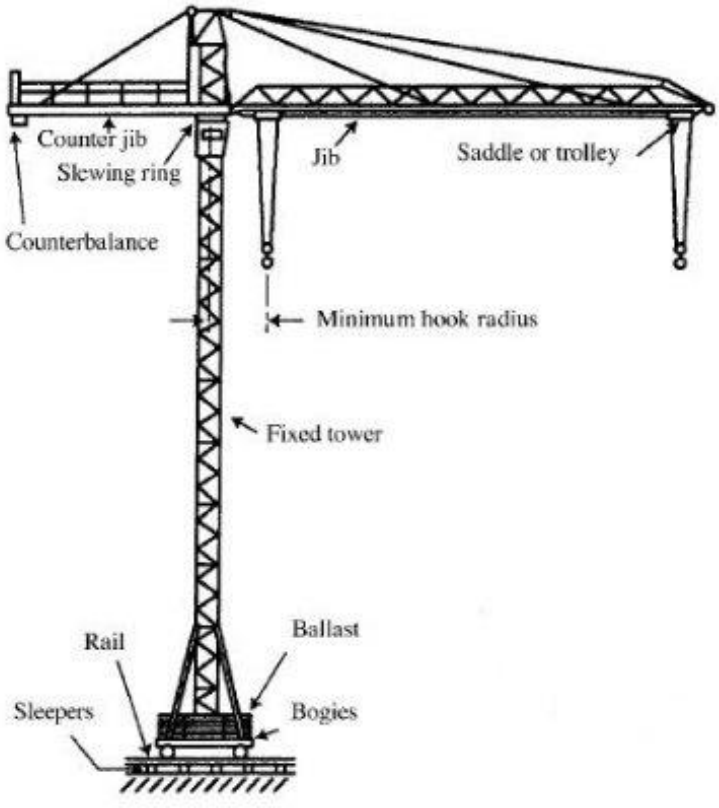

Figure 2: Tower Crane

There are further divisions in both the types of cranes as listed below:

1. Mobile Cranes:
    - Crawler cranes
    - Truck mounted cranes
        - Telescoping boom
        - Lattice boom
    - Rough terrain cranes
    - All terrain cranes
    - Modified cranes
2. Tower cranes:
    - Top-slewing (Fixed tower) cranes
    - Bottom-slewing (slewing tower) cranes
        - Lattice-type mast
        - Tubular Mast
        - Self-erecting Cranes
    - Travelling tower cranes

The basic difference: In mobile cranes, complete superstructure is mounted on a mobile or moving platform i.e. wheels or crawler tracks. Their advantages are mobility and ability to carry greater loads. While in tower cranes, these advantages are replaced with high lifting height, increased stability, good working radius and taking very limited space. Their main superstructure must be installed and dismantled and does not move in the duration of their use. (Construction Planning, Equipment and Methods 8th edition)

2.3 Causes of recently occurring crane accidents

2.3.1 General Causes

Throughout the literature, there are numerous causes of crane accidents. After going through the various research papers and texts, here is a summarized list of causes:

1. Overturning of crane
2. Structural Failure of crane(boom/cable)
    a. Due to Design flaws
    b. Due to overloading or mishandling of load
3. Operator errors
4. Electrocution/contact with powerlines
5. Struck by Load
6. Falls
7. Crushed during installation/dismantling of tower cranes
8. Lack of safety training and operator licensing (personnel in and around crane operations)
9. Environmental conditions (Harsh weather)
10. Lack of regulations or not following regulations

(Beavers et al 2006, Marquez et al 2014)

However, these causes can be basically divided into four categories:

- Engineering Errors: Accidents resulting due to improper Installation/Dismantling lifting of load (Lifting Mechanism of Crane), problems in manufacturing or design, Under designed Foundation, Unsafe Equipment, etc.
- Human Errors: Mistakes made by Operator, Riggers, Signalman, Workers, etc., Placement of Crane on Unstable Ground, Not Following Regulations, Lack of Competency,
- Operational/Management Errors: Accidents resulting from Improper Lifting of Load (Overloading or Mishandling of Load), Struck by Load, Job Site Conditions like Poor Site Management, Poor Illumination, etc., Lack of Maintenance, Inadequate Inspections, Less consideration given to Site Safety, Lack of Regulation Enforcement, etc.
- Environmental Impact: Extreme weather conditions like high wind, extreme Temperature, Mist, etc. which may have adverse effect on the Equipment (Crane in this case) or the workers on the work site; Natural Disasters like Earthquakes, Floods, etc.

The causes categorized above can fall in other categories too depending on the accident scenario. All the categories mentioned above are highly inter related to each other especially the Operational and Human Errors. Accidents may occur as a result of a single cause or combination of different causes, and usually its the latter. In a typical accident, there will be a main cause which led to accident and then there are contributing factors to the it. Many at times, number of factors combine together to

cause a catastrophe. If these factors are controlled and monitored, many lives can be saved and huge economic losses can be prevented. This is referred to as Multiple Causation model. Further, a Model named “Swiss Cheese Model” also described a similar concept that multiple factors or causes must align together to result in an accident. The reason its called Swiss Cheese Model is that it compares the real events of accident to Swiss Cheese slice, where many different holes in the slice align together at a particular angle to reveal one open hole through the complete Slice.

(Reason, J., et al 2006, Lindley and Roger 2008, Hamid, A. R. A., et al 2008, Zrnic, Nenad D. et al 2011)

2.3.2 Causes of recently occurring crane accidents

Even to this day, crane accidents continue to occur all around the world. Some of them go unrecorded while some are scrutinized for the exact cause. Here are some of the famous case studies of crane accidents:

1. Accidents in Saudi Arabia

a. Makkah crane collapse: A crawler crane fell over on the east side and crashed through the roof of Masjid al-Haram, Makkah, Saudi Arabia. About 111 people were killed and 394 injured. "The accident was recorded as the deadliest accident in the modern history".

   The reasons cited were strong winds (speed more than 40kph/25mph) due to fierce storm in the area. Some reports also mentioned that the operator did not secure the long boom to withstand the high winds.

   (https://en.wikipedia.org/wiki/Mecca_crane_collapse)

b. Jubail crane collapse: "The boom of a telescopic truck crane collapsed while erecting an electricity pylon in Jubail, Saudi Arabia". Overloading was main cause of this accident. Fortunately, no one was injured in the accident.

   (http://www.craneaccidents.com/2010/05/report/crane-boom-folds-in-jubail/)

c. Jeddah crane collapse: "Two people were injured when a construction crane came crashing down on top of two passing vehicles and a government building during morning rush hour in Jeddah's Al-Rawdah district." A construction worker and vehicles driver was injured in the accident. The cause of this accident was the crane was very old and inspection was scheduled.

(http://www.craneaccidents.com/2009/03/report/two-hurt-as-crane-crashes-down-on-cars/)

d. Crane overturn in Makkah: "A Yemeni construction worker was killed and two others seriously injured when they fell from a crane as it overturned.

The three fell 20 meters off a crane while working on the Al-Jamrat Bridge project in Makkah. According to Civil Defense, the accident was due to an excess load causing the crane to overturn"
(http://www.craneaccidents.com/2008/08/report/one-dead-two-injured-on-al-jamrat-bridge/)

2. Accidents in other places:

a. The Miller Park crane collapse: A huge crane (340ft boom, 200ft jib length) called the big blue overturned while setting a roof panel section of the stadium (Milwaukee, Wisconsin, USA). The cause of the accident was the decision of the general contractor to carry out the lifting operation in adverse weather conditions (high wind speeds). It led to death of three workers and loss of millions of dollars.

(B. Ross et al 2007)

b. Rotterdam crane collapse: A travelling tower crane collapsed onto a 24 storey high rise flat in Rotterdam. It was due to faulty design of the crane; the jib was more flexible than required which led to load surpassing the maximum load moment and making it unstable. The crane operator was killed in the accident.

(P. Swuste 2013)

c. Bellevue crane disaster: A large tower crane (210ft) crashed into three neighborhood buildings in Bellevue, Washington, USA. The cause of failure was faulty design of the crane structural base which could resist the overturning moments. The tie-assembly was eliminated by the contractor and was neither communicated to nor inspected by the designer.

(B. Mc Donald et al 2011)

d. New York crane crash (2008): Before the Makkah crane accident, this accident was regarded as the deadliest. A 200 feet tall tower crane collapsed onto some buildings and completely destroyed a townhouse. 7 people died in the incident and 24 were injured. The collapse was caused due to failing of polyester slings holding the collar at the 18th floor. Upon further investigation, improper usage of the polyester slings and inadequate number of slings and improper connection of the sling came out to be the precise causes of the accident.

(http://failures.wikispaces.com/303+East+51st+Street+NY+Tower+Crane+Collapse)

There are many crane accidents that occurred in New York and other places around the globe. A few were listed here to gain an understanding of the causes and the losses that resulted due to the accident.

CHAPTER 3

RESEARCH METHODOLOGY

3.1. Research Methods

After an extensive literature review, the causes of crane accidents, their preventive measures and factors affecting crane safety were obtained. To investigate the frequency of Crane Incidents in Saudi Arabia, their causes, standards used, etc. Data must be obtained regarding the same from the construction sites in the Eastern Province of Saudi Arabia. Since this is a Qualitative Research i.e. data is subjective, Interviews and Questionnaire survey method is the best suited method. (Fellows & Liu 2008)

The respondents were requested for an appointment for and interview. A semi-structured interview was taken keeping the questionnaire as reference. If the respondent was unable to set an appointment, a structured questionnaire was sent to him/her to fill and return at their ease.

The questionnaire was planned to be sent to 94 companies where personnel in different positions will be expected to respond. Personnel include Project Managers, Construction Managers, Equipment Managers, Site Engineers, Safety Engineers, Crane Operators and workers that include riggers, signalmen etc.

After collection of data, it was analyzed using various Statistical Techniques, results were summarized and discussed and conclusions and recommendations were put forth.

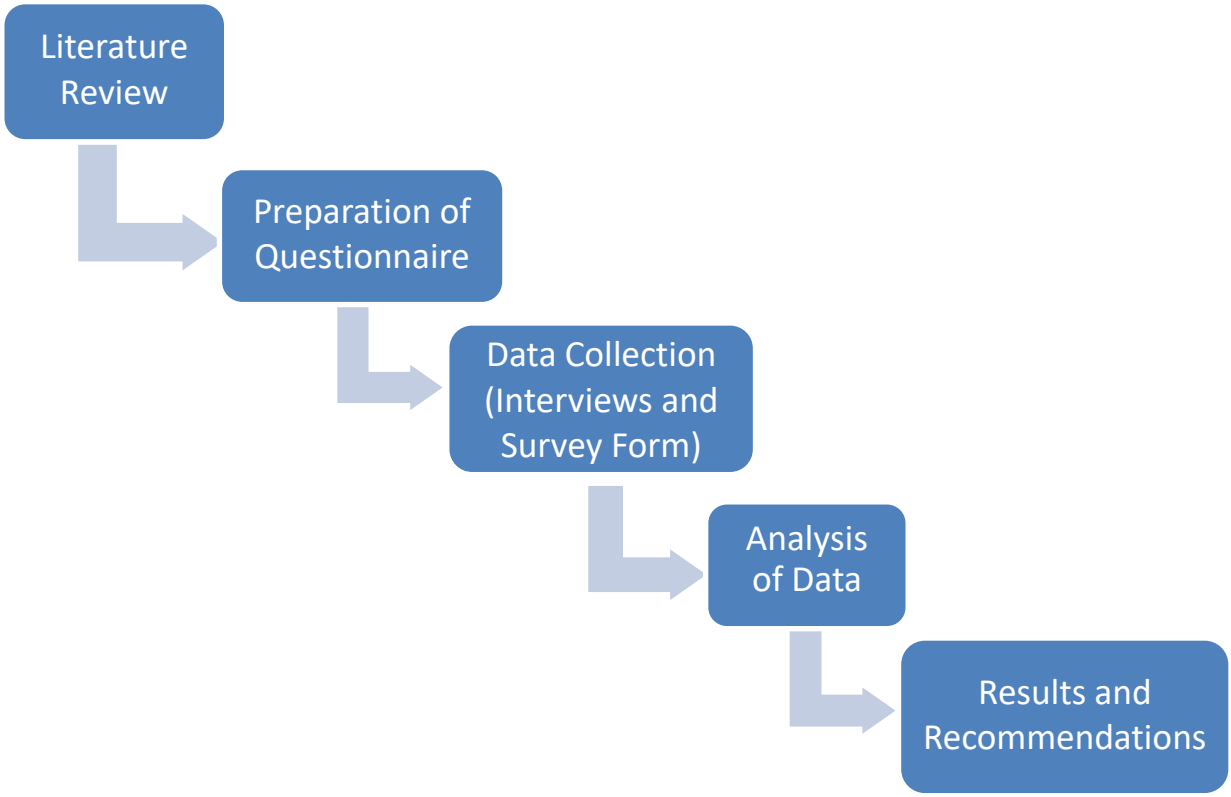

Figure 3:Flow chart showing Methodology of this Research

3.2 Data Collection

3.2.1 Data Source

The required data was collected from a list of major construction companies in Saudi Arabia. The key respondents were Project managers, construction managers, equipment managers, site engineers, safety engineers, contractors, crane operators and workers that include riggers, signalmen etc.

3.2.2 Tool – Developed Questionnaire

A systematized questionnaire survey was used to collect the data which was distributed in both paper-form and through web.

The questionnaire has two divisions. The first division comprises demographic questions seeking information about the respondents of the questionnaire while the second division focusses on potential questions required to accomplish the objectives.

3.3 Population and sample Size

The population of the study consists of all companies that directly or indirectly influence the crane safety in Saudi Arabia. There are currently about 94 construction contracting companies in the Eastern Province of Saudi Arabia (Source: Municipality website, as of 1st March 2016,). Further, the above number includes grade 1, grade 2 and grade 3 "BUILDING" contractors. (http//: www.momra.gov.sa)

3.3.1 Sample Size

Based on population chosen, the minimum sample size to obtain adequate results is calculated by using the equation (Kish, 1995)

$n^o = (p*q)/v^2$

$n = n^o / (1 + (n^o / N))$

Where: n^o = First estimate of sample size

p = The proportion of characteristic being measured in the target population

q = 1 – p

v = The maximum percentage of standard error allowed

N = The population size

n = Sample size

For getting maximum sample size, the values of (p) and (q) was taken as 0.5 for both. The maximum standard error (v) allowed was taken as 10%.

$$n^0 = \frac{0.5 * 0.5}{(0.1)2} = 25$$

$$n^0 = \frac{25}{\left(1 + \left(\frac{25}{94}\right)\right)} = 19.74$$

Sample size required (minimum) = 20

3.3.2 Difference between Company Grades

There are 94 companies which identify as Grade 1, Grade 2 and Grade 3 Building Contractors in the Eastern Province of Saudi Arabia. Out of these, 23, 30 and 41 are Grade 1, Grade 2 and Grade 3 companies respectively.

These companies are enlisted on the MOMRA website which is in Arabic. The summary of criteria listed on the website for classifying contractors into Grade 1, 2 or 3 is as follows:

1. The Skill Aspect of the contracting company:
    - Policies and goals set by the company
    - Current and Future relations with owners
    - Size of the company and Size of Projects taken
    - Ability of the Contractors to implement project
    - The ability of the contractor to handle the highest load of continuous work over a long period
    - Skills and experience of the Company staff (Directors, Engineers, Technicians, etc.)
2. The Financial Aspect of the contracting company:
    - Budget and Cash Control
    - Ability to obtain significant revenue necessary to continue
    - The capacity and efficiency of operational management for profit
    - Describes the ability to use the assets to produce income
    - Accounting systems and procedures and calendar management accounts

It is interesting here to note that higher grade companies are more in involved in large scale projects and lower grade companies are occupied with small, sometimes medium scale projects.

CHAPTER 4

DATA ANALYSIS, RESULTS AND DISCUSSION

This chapters details the findings obtained from the survey.

4.1 Descriptive Statistics

To represent data in Tabular and Graphical form, Descriptive Statistics was used.

4.1.1 Tabulation and Cross-Tabulation

Cross tabulation is a statistical technique that displays depicts the categorical data in a two-way tabular form. It is used to analyze data and compare relationship between different variables in data.

4.2 Statistical Methods

4.2.1 Q-Q Plot

The Q-Q Plot (Quantile-Quantile Plot) is a probability plot used to compare any two probability distributions. This is a graph which shows the deviation of one probability distribution with respect to another. It is commonly used to check the deviation of a particular probability distribution from Normal Distribution. Q-Q Plots were used in this research to check whether various distributions can be assumed as Normal or not. This is used to apply further Parametric tests. (Kohler & Kreuter 2009)

4.2.2 ANOVA (Analysis of Variance)

ANOVA or Analysis of Variance is a statistical test to find out the significance of statistical difference between several groups i.e. if the means of these groups differ or not significantly. This test is only applicable when the data is normally distributed. In other words, this test cannot be applied if the data has any distribution other than Normal Distribution. SPSS software was used to analyze the data. The results and tables obtained are shown.

If μ_1, μ_2 and μ_3 are population means of three groups (Grade 1, Grade 2 and Grade 3 in this research) then the null hypothesis and alternate hypothesis are:

- Null hypothesis: All means are equal
- Alternate Hypothesis: Not All means are equal

Which translates to:

$$H_0: \mu_1 = \mu_2 = \mu_3$$

$$H_a: \mu_1 \neq \mu_2 \neq \mu_3$$

The confidence level was taken as 95%, hence the level of significance, $\alpha = 0.05$.

Data is fed into the SPSS software and results in the form of tables and values are obtained. The significance value, or the p-value is observed to accept or reject the null hypothesis.

- If p-value is greater than α, then the null hypothesis is retained and there is no difference between the group means.

- If the p-value is less than or equal to α, then the null hypothesis is rejected which yields that the group means are significantly different.

(Anderson 2015)

4.2.3 Post Hoc analysis

To further check the significant difference between any two groups of the population, Post Hoc analysis is used. Various post hoc tests are available. For this research, Tukey 's HSD (Honest Significant Difference) test will be used for pairwise comparisons i.e. Grade 1 vs Grade 2, Grade 2 vs Grade 3 and Grade 1 vs Grade 3. This will show specifically which two group means are different from each other. Tukey's test is best suited for this research as the sample sizes of each grade are not equal. SPSS software will be used to obtain the results for Tukey's test.

If μ_i and μ_j are population means of any two group combinations (between Grade 1, Grade 2 and Grade 3 in this research) then the null hypothesis and alternate hypothesis are:

- Null hypothesis: The two means are equal
- Alternate Hypothesis: The two means are not equal

Which translates to:

$$H_0: \mu_i = \mu_j$$

$$H_a: \mu_i \neq \mu_j$$

The confidence level was taken as 95%, hence the level of significance, $\alpha = 0.05$.

The significance value, or the p-value is observed to accept or reject the null hypothesis.

- If p-value is greater than α, then the null hypothesis is retained and there is no difference between the two group means.
- If the p-value is less than or equal to α, then the null hypothesis is rejected which yields that the two-group means are significantly different.

(Hinton 2004)

4.3 Other Methods

An Importance Index formula was used to transform the ranked data into meaningful information. Following formula was used (Dominowski, 1980):

$$Importance\ Index = \frac{\sum_{i=0}^{3} a_i x_i}{3 \sum_{i=0}^{3} x_i} \times 100\%$$

Where: i = response category; where i = 0,1,2,3

a_i = Given Weight to responses

x_i = is a variable representing frequency of i

x_0 = frequency of "Highly Significant/Often Used" response corresponding to a_0= 3

x_1= frequency of "Sometimes Significant/Used" response corresponding to a_1 = 2

x_2= frequency of "Rarely Significant/Used" response corresponding to a_2= 1

x_3= frequency of "Never Significant/Used" response corresponding to a_3= 0

A scale used by Hassanain & Juaim, 2011 was implemented here to categorize the importance index. This scale is shown in Table 1.

Table 1: Example for Importance Index Classification

Importance Index	Classification
0–<12.5%	Not significant
12.5–<37.5%	Low significance
37.5–<62.5%	Significant
62.5–<87.5%	High significance
87.5–100%	Very high significance

4.4 Computer Software

The data was exported from online google forms in the form of excel sheet. Information was extracted as per requirement and major analysis work and graphs were prepared and executed in excel. Also, SPSS software (**Statistical Package for the Social Sciences)** was used to analyze the significant differences between values. This greatly reduced the time and effort required to manually analyze the data.

4.5 Demography Analysis: General Information

The first part of the questionnaire deals with demographic information of the respondents i.e. their position, experience, etc. The following graphs depict the information.

We had obtained the minimum sample size required to analyze the information i.e. 20 companies. Since the population is a very low number and is within the limit of resources assigned to this Research, best measures were taken to communicate with all 94

companies to get responses. Table 2 gives the information about the number of companies surveyed and their grade.

Table 2:Number of Companies Responded

Company Grade	Number Responded	Total
Grade 1	20	23
Grade 2	15	30
Grade 3	9	41
Total	44	94

Response percentage = $\frac{44}{94} \times 100 = 46.8\%$

4.5.1 Position of the Respondents

Different positions of persons who responded are Project Managers, Health and Safety Managers (HSE Managers), Safety Engineers and Safety Supervisors. Figure 4 illustrates the distribution:

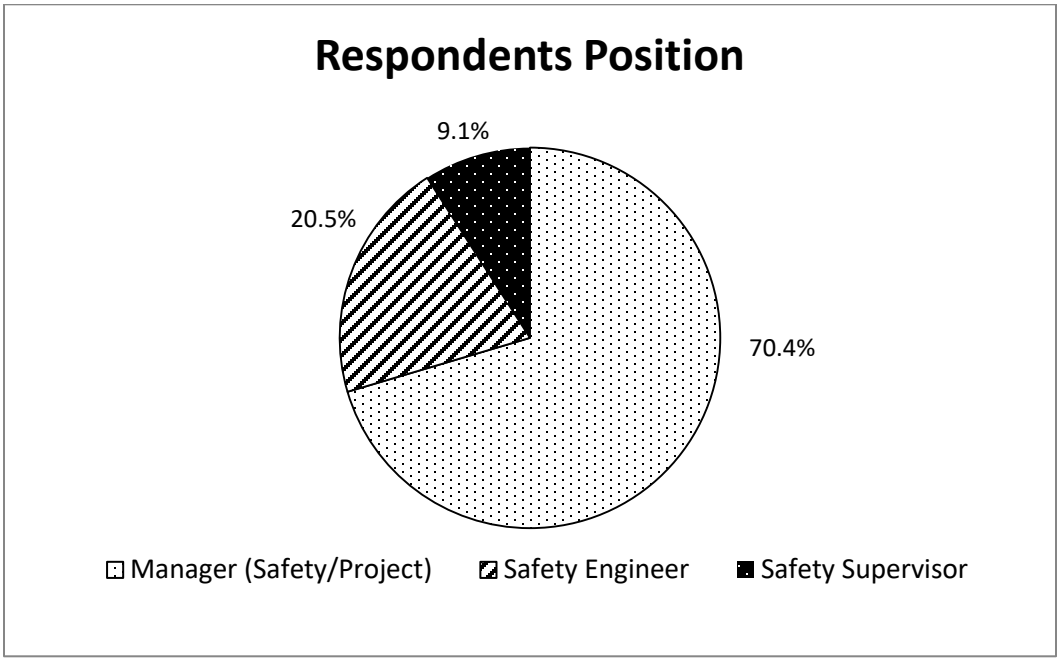

Figure 4:Respondent's Position

4.5.2 Years of Experience

We can observe from figure 5 below that about 50% of the respondents have experience at least above 15 years. Moreover, 86.4% of the respondents have experience above 10 years. This has increased the diversity and proficiency of the information obtained.

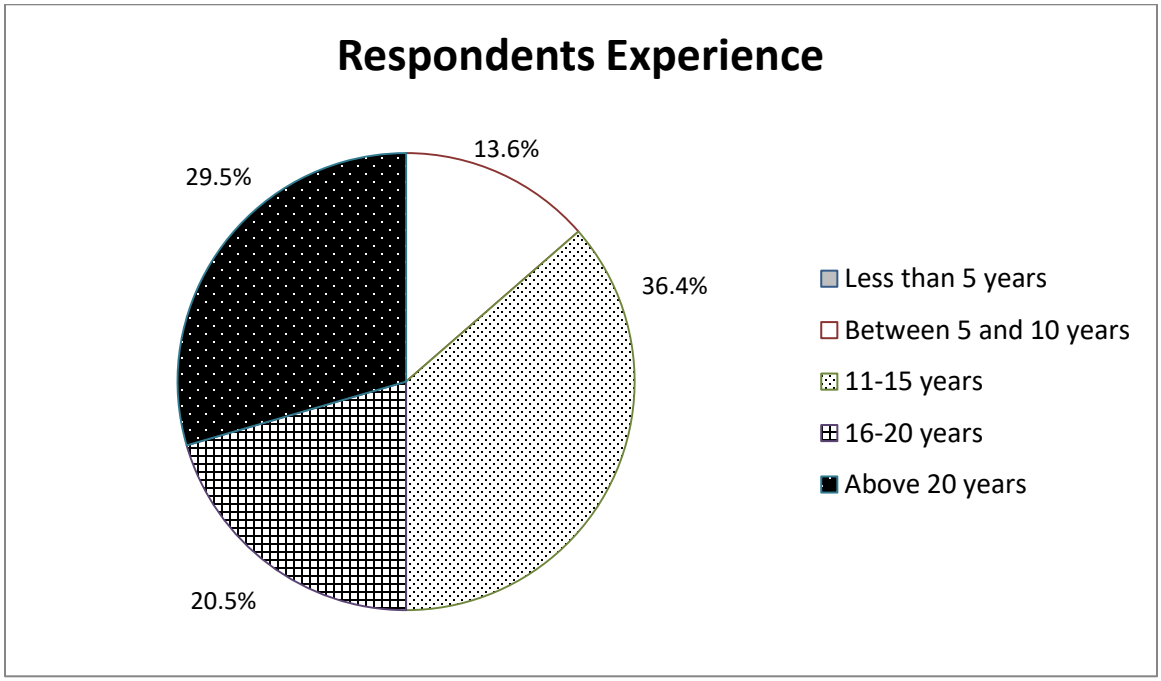

Figure 5: Respondent's Experience

4.6 Frequency of usage for Different Crane types

The respondents were asked to rate the usage (from 1 to 4) of three types of cranes i.e. Mobile Crane, Tower Crane and Other Cranes (Bridge crane/Container Crane, etc.) in K.S.A. Importance Index was calculated and the figure 6 summarizes it:

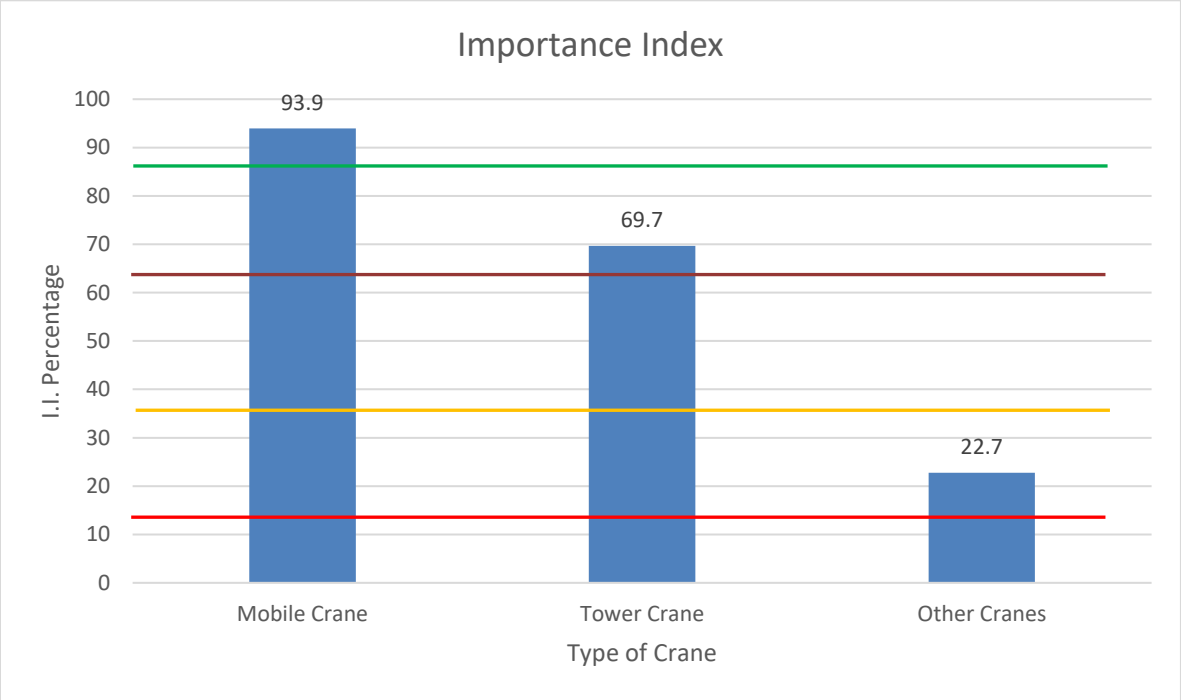

Figure 6:Frequency of Crane Usage

Table 3: Importance Index for Crane Usage

Importance Index	Classification
0–<12.5%	Not Used
12.5–<37.5%	Rarely used
37.5–<62.5%	Sometimes Used
62.5–<87.5%	Often Used
87.5–100%	Always Used

We can observe that Mobile Cranes fall in the category of “Always Used” (Refer Table 6). Almost all of the respondents said that Mobile Crane is always used on site. Even the respondents who were using Tower Crane for a major portion of their works said that initially until the foundation of the building is completed and the Tower Crane base is established, Mobile Crane is used. Mobile Crane is also used for the installation and dismantling of Tower Crane.

Tower Cranes fall in the category “Often Used”. Many large companies usually own Tower Cranes and have their own operator. This will decrease the per cycle cost of using Tower Cranes. However, as mentioned above, even they must use Mobile Cranes in some stages of the project.

Other cranes like Side Boom Crane, Bridge Crane, Container, Crane, etc. have a very low Importance Index indicating that they are rarely used by the building contractors. It is Important to note that these types of Cranes are mostly used in Warehouses for Heavy lifting which comes under the category of Industrial Contractors. These types of contractors are outside the scope of this research.

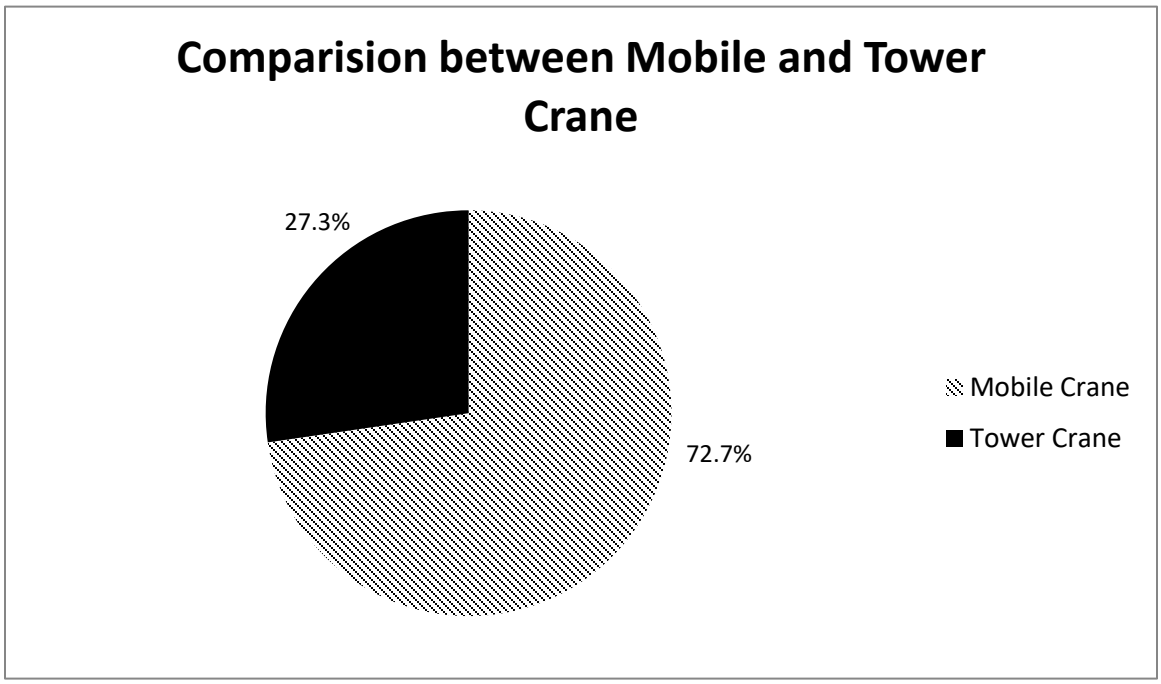

Figure 7: Mobile Crane vs Tower Crane

The respondents were then asked if they had to select any one type of crane that is mostly used in the Construction Industry, which would it be. 72.7% of them responded Mobile Crane and 27.3% responded Tower Crane. This corroborates with the value of the Importance Index obtained previously. Hence, we can deduce that Mobile Crane usage is dominant over that of Tower Crane in the Saudi Arabian Construction Industry. This is similar to the U.S. construction industry where the Mobile Crane Usage is dominant.

4.7 Standards enforcement on Contractor

The respondents were asked about the Agency or Organization that Enforces safety standards upon them. Most of the respondents answered that the safety standards they follow are mainly dependent on the client or owner they are working for. This means that when the contractors are awarded the contract, it includes a section about the standards of safety that the contractor should comply. These standards are different for different Clients depending upon the importance they give to safety and their ability to allot resources for safety.

Saudi Aramco was the client for many of them (around 45%), hence they followed Aramco standards of safety. Further, they mentioned that Aramco has the highest standard for safety in Saudi Arabia and they are very strict about following their standards. The respondents mentioned that these standards were derived from the U.S. safety standards i.e. OSHA standards and were modified to suit to the working environment in K.S.A.

Other major clients included Royal commission, Civil Defense, LEEA (Lifting Equipment Engineers Association), etc. who enforced high standards of safety. The contractors had to follow the standards of whichever client they were working for. But these standards were lower when compared to that of Saudi Aramco.

In addition, many large companies worked for different clients mentioned above. In case they are awarded a project where the client doesn't enforce any standards, the company followed their own standard that they could afford for the project. This company standard was derived from the various standards of the clients they previously worked for.

Sometimes, in this case, they were forced to rule out some important safety regulations if the client didn't grant enough budget for safety operations. This highlights that the clients play a crucial role in implementing safety and to prevent accidents in the construction industry. Safety starts and ends with the client. There should be national legislation that governs the sufficient level of safety standard implementation with respect to the size of the project handled by the Client.

4.8 International Standards in K.S.A

The respondents were given the choice to select one or more international standards which they think are mostly adopted and followed in Saudi Arabia. The options were:

- OSHA (Occupational Safety and Health Administration)
- NEBOSH (National Examination Board in Occupational Safety and Health)
- IOSH (Institution of Occupational Safety and Health)
- Combination/Other standards

Figure 8 summarizes the results obtained:

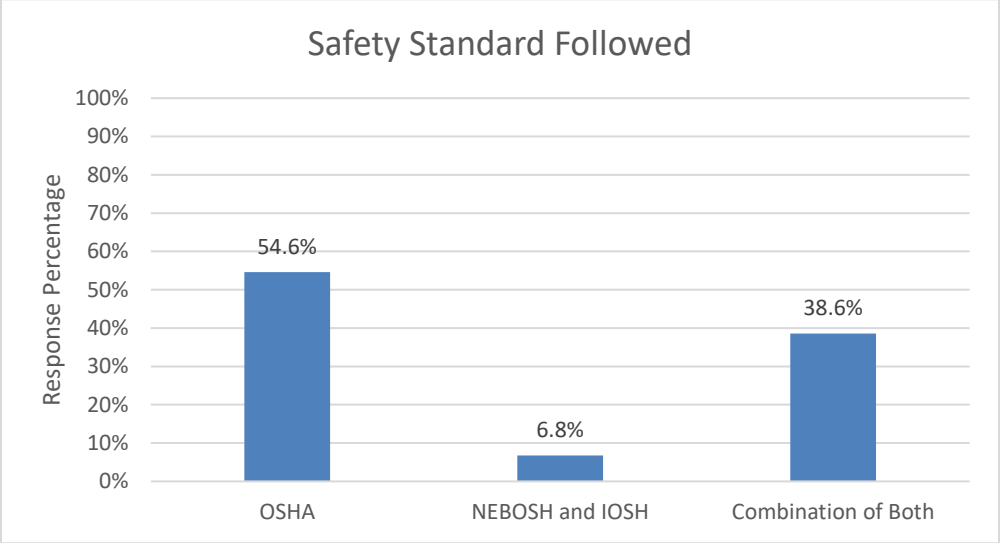

Figure 8: International Standard in K.S.A.

Out of 44 respondents, 93.2% of them followed only OSHA standard or combination of OSHA and other standards. Many of them followed different standards depending on the client requirement. The fact that 93.2% of the respondents selected OSHA leads us to safely deduce that OSHA standards are adopted by the client/owner/government organizations in KSA.

However, only 6.8% of the companies surveyed followed the UK safety board standards like NEBOSH and IOSH. Further, the companies who were adopting the combination method said that they were trying to eliminate the drawbacks of both the standards and adopt an overall safer standard. In fact, they were preferring NEBOSH standard over OSHA saying that the UK standards are being timely updated more rapidly than US standards. Moreover, NEBOSH courses deal with both managerial side of safety and safety standard. Therefore, they are preferring to hire safety personnel having a NEBOSH certificate or diploma.

4.9 Following Standards in work

The respondents were then asked to what extent these standards were implemented while execution of work. Figure 9 summarizes it:

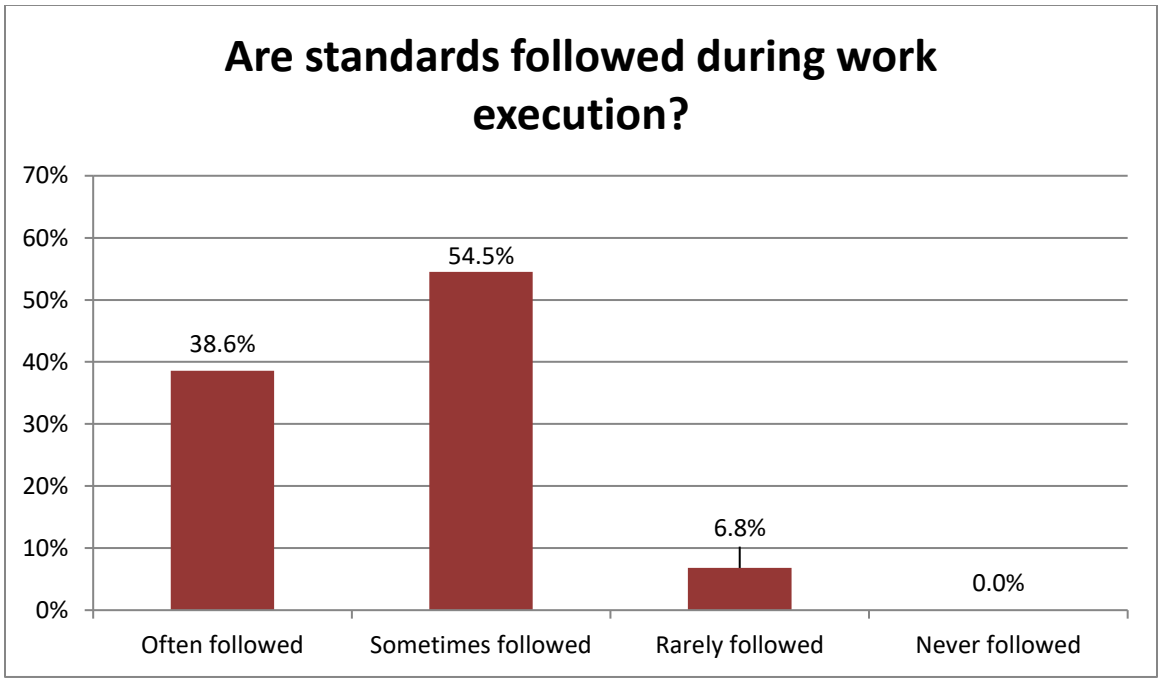

Figure 9: Following Standards

As we can observe, 38.6% of the respondents have the opinion that the safety standards are often followed and implemented. This is the case if the client of the company is Saudi Aramco for all their projects. Saudi Aramco is widely known for firmly implementing rules and regulations. Hence the safety standards are adhered to in such cases.

However, more than half (54.5%) responded that the standards are only sometimes followed and 6.8% responded Rarely Followed.

Table 4: Following Standards vs Company Grade

	Often	Sometimes	Rarely	Never	Importance Index
Grade 1	25%	22.7%	0%	0%	84.1%
Grade 2	11.45%	20.5%	2.2%	0%	75.5%
Grade 3	2.2%	11.4%	4.5%	0%	62%
TOTAL	**38.6%**	**54.5%**	**6.8%**	**0%**	

To further analyze the response, the table 4 was prepared which shows the total response percentage with respect to the company grade. In addition, Importance Index was calculated which summarized the responses into percentage. Importance Index indicates the level to which the company grade follows rules and regulations.

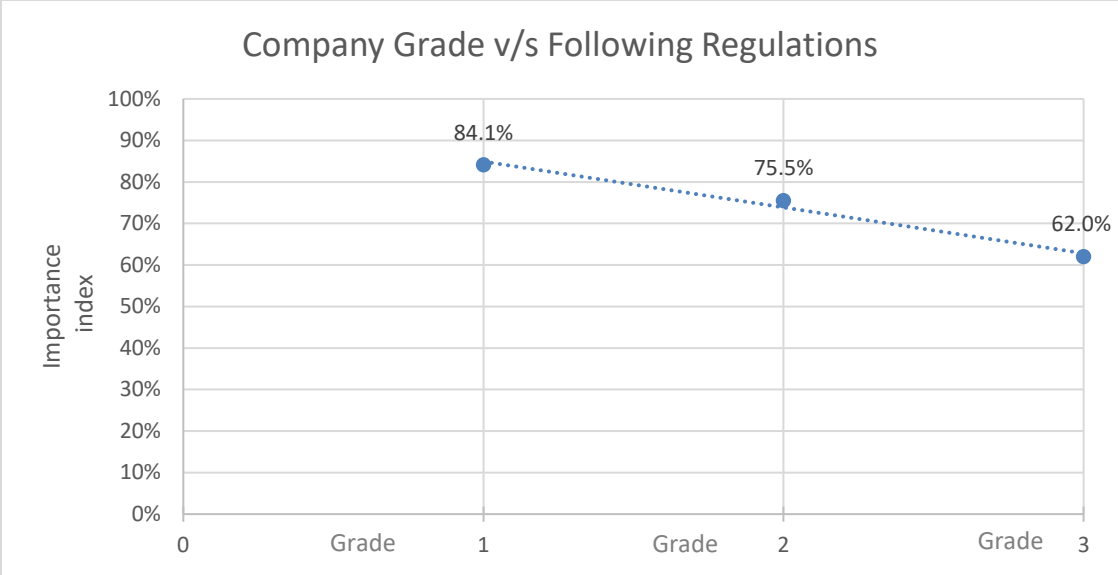

Figure 10: Company Grade v/s Following Regulations

Table 5: Importance Index for Company Grade v/s Following Regulations

Importance Index	Classification
0–<12.5%	Never Followed
12.5–<37.5%	Rarely Followed
37.5–<62.5%	Sometimes Followed
62.5–<87.5%	Often Followed
87.5–100%	Always Followed

A graph was plotted between the Company Grade vs Importance Index Obtained (Refer figure 10). The slope of the trendline above graph is negative. From the graph, we can notice as the company grade decreases, the tendency to follow the safety regulations decreases. The reason for this is Most of Grade 1 and some of Grade 2 companies deal

with clients with high or acceptable standard of safety standards. Many of the Grade 3 companies deal with private clients in small or medium scale projects. The increase in proficiency of Grade 1 and Grade 2 companies by doing projects with such clients increased their chance of being awarded the project in the future from those clients, decreasing the chance of Grade 3 companies to be awarded the contract at the same time. Thus Grade 3 companies were limited to the private sector thus difference in level of following regulations.

The contractors are not the only ones to blame. In the interviews, the managers revealed that the clients didn't allot budget separately for safety while inviting bids i.e. safety was not an item on the list. Therefore, the companies tried to distribute appropriately the cost of safety in all the items on the list. But this increased the overall tender cost hence highly increasing the chances to lose the bid. To win the bid, they were compelled to neglect safety and they had to do so unwillingly.

However, some private clients allotted a specific amount of budget to safety but it was very limited. For e.g. One respondent said that if safety would cost SR100,000 in the project, the client would only allot SR20,000. They again faced the situation above, to unwillingly accept that amount to not lose the bid. Hence the company lowered their standards of safety which included neglecting many aspects of safe work execution.

4.10 Near Misses and Accidents

This question mainly focused on the near misses or accidents the respondents have encountered during their work experience in KSA. The respondents were asked to enter the number in the box if they experienced more than one near miss or accident.

4.10.1 Near Misses

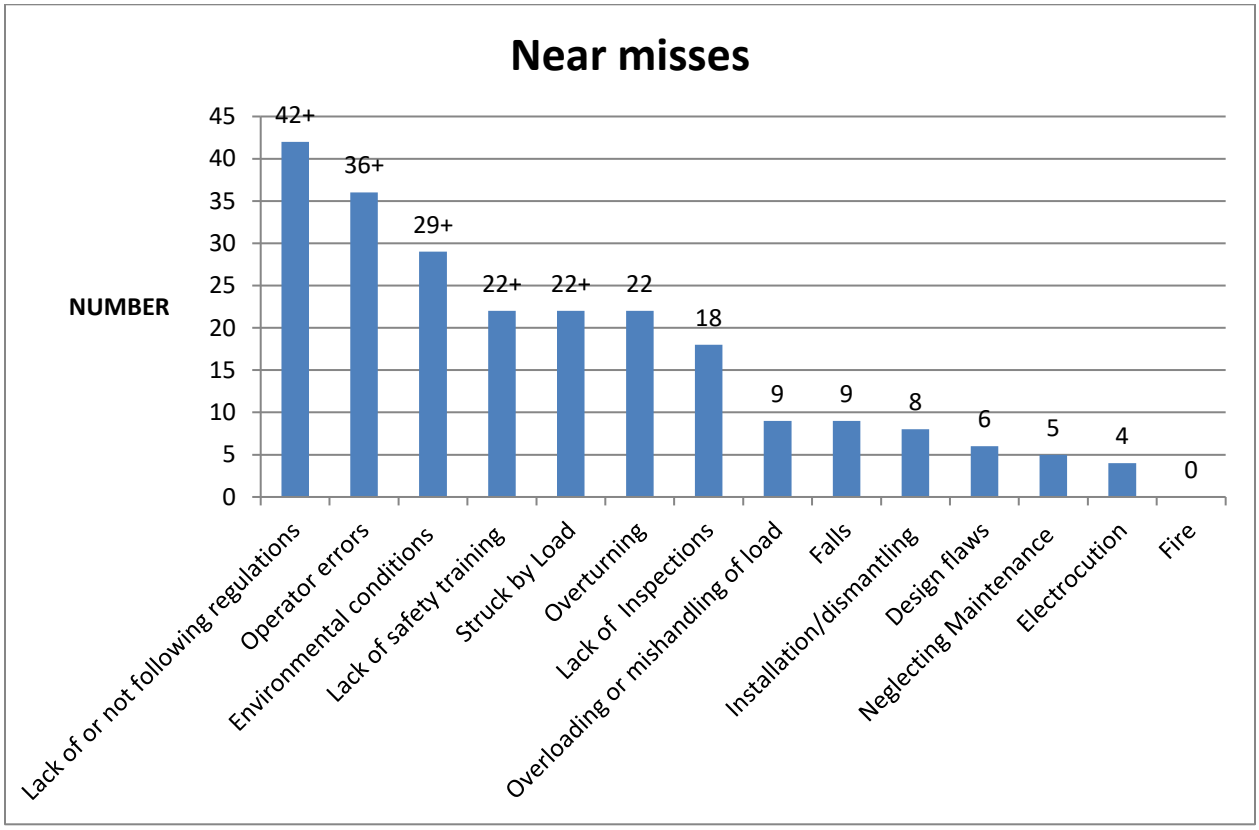

Figure 11: Near Misses Data

Table 6: Near Misses data

Rank	Cause of Near miss	Near
1	Lack of regulation Enforcement or not following regulations	42+
2	Operator errors/mistakes	36+
3	Environmental conditions (Harsh weather like wind, etc.)	29+
4	Lack of (or) No proper Inspections	22+
4	Lack of safety training and licensing (personnel in and around	22+
5	Overturning of crane	22
6	Struck by Load	18
7	Falls (from heights)	9
7	Overloading or mishandling of load	9
8	Crushed during installation/dismantling of tower cranes	8
9	Structural Failure of crane due to Design flaws	6
10	Neglecting required Maintenance	5
11	Electrocution/contact with power lines	4
12	Fire	0

When we observe the number of Near Misses with respect to grade of the company, we find that there are more than 179 Near Misses of which 29% are from grade 1, 36.87% from grade 2 and 34% from grade three. Dividing the number of Near Misses by the number of companies surveyed in the respective grades, we have 2.6 Near Misses per company in grade 1, 4.4 Near Misses per company in grade 2 and 6.8 Near Misses per

company in grade 3. Hence it is evident that there are more Near Misses per company as we move from grade 1 to grade 3.

Figure 12 shows the relation between company grade and average NEAR MISSES per company:

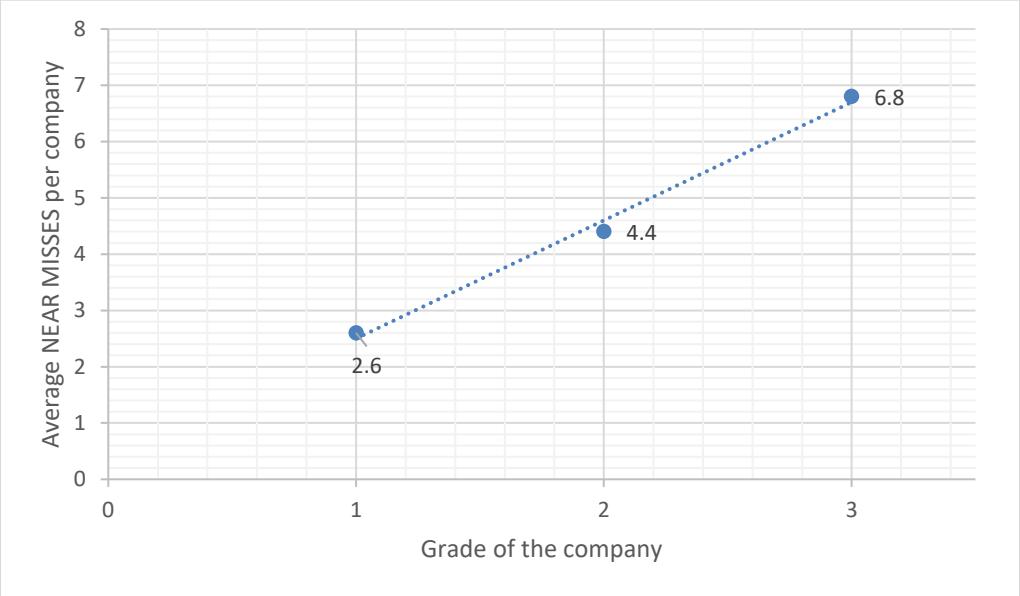

Figure 12: Company Grade vs Average NEAR MISSES per Company

In the graph, we can notice that there is a as we move from grade 1 to grade 3, we see that number of Near Misses per company increases. This relates to the fact that companies in lower grade take more private projects and give negligible attention to safety on the site.

From Table 6 and Figure 11, we can observe that the highest rate of near misses is due to Lack of regulation Enforcement or not following the regulations. The second highest cause of near misses is operator errors. The complaint of most of the respondents was despite having operator license, the operators either didn't pay attention towards safety training procedures or were careless about crane operations. The next most common

causes of near misses are Environmental conditions, Lack of or No Proper Inspections, Lack of safety training, overturning of crane and Struck by Load. The occurrence was above or around 20. Based on the categorization, Human errors and Operational/Management errors are dominant when it comes to near misses on work sites.

4.10.1.1 Adverse Environmental conditions:

Safety standards regarding crane safety strictly states that crane operations should be immediately halted on foreseeing or encountering adverse weather conditions. For example, regarding high wind speeds, there is a wind speed limit type and specifications of the crane. Usually this limit is around 22 mph. beyond this limit, no heavy loads should be lifted and work is stopped if the situation worsens. For e.g. OSHA standard number 1917.45(g)(3) states the following:

Crane should be fitted with an operable wind-indicating device

- The wind indicating device shall provide a visible or audible warning to alert the operator of high wind conditions
- When wind velocity reaches the shutdown speed, work is to be stopped and the crane secured.

Some respondents said that these conditions were overlooked and the crane operations weren't stopped which is linked to the most prominent cause of near misses and accidents i.e. Lack of regulation Enforcement or not following regulations.

4.10.1.2 Lack of or No Proper Inspections:

The purpose of inspections is to detect anything inappropriate with regard to safety of equipment or its safe operation as a whole and take suitable measures to repair of fix the problem. Hence it is done periodically.

The respondents said that third party certificates were issued by companies after inspecting for the safety of crane equipment and its operations. They were authorized by the government and sometimes clients instructed the contactors to certify their crane from a particular company. The period of inspections depends upon the contract duration i.e. if its short, inspection is done only once. If the contract duration is long, inspections are done every half yearly or annually.

In addition to obtaining third party certificates, it is the contractor's responsibility to carry out daily inspection checklist for safe crane operations. If they observe anything improper or out of place while inspection, they should take right measures without delay to resolve the problem. But the respondents mentioned in particular that despite carrying out daily inspection, relevant maintenance wasn't carried out when it was required. The safety inspector would neglect the maintenance requirement, checking the item on the list (indicating as if there was no problem at all). The reason the inspectors gave was they never experienced any accident due to not rectifying the problem. It was apparent that they wanted to save time and money.

4.10.2 Accidents

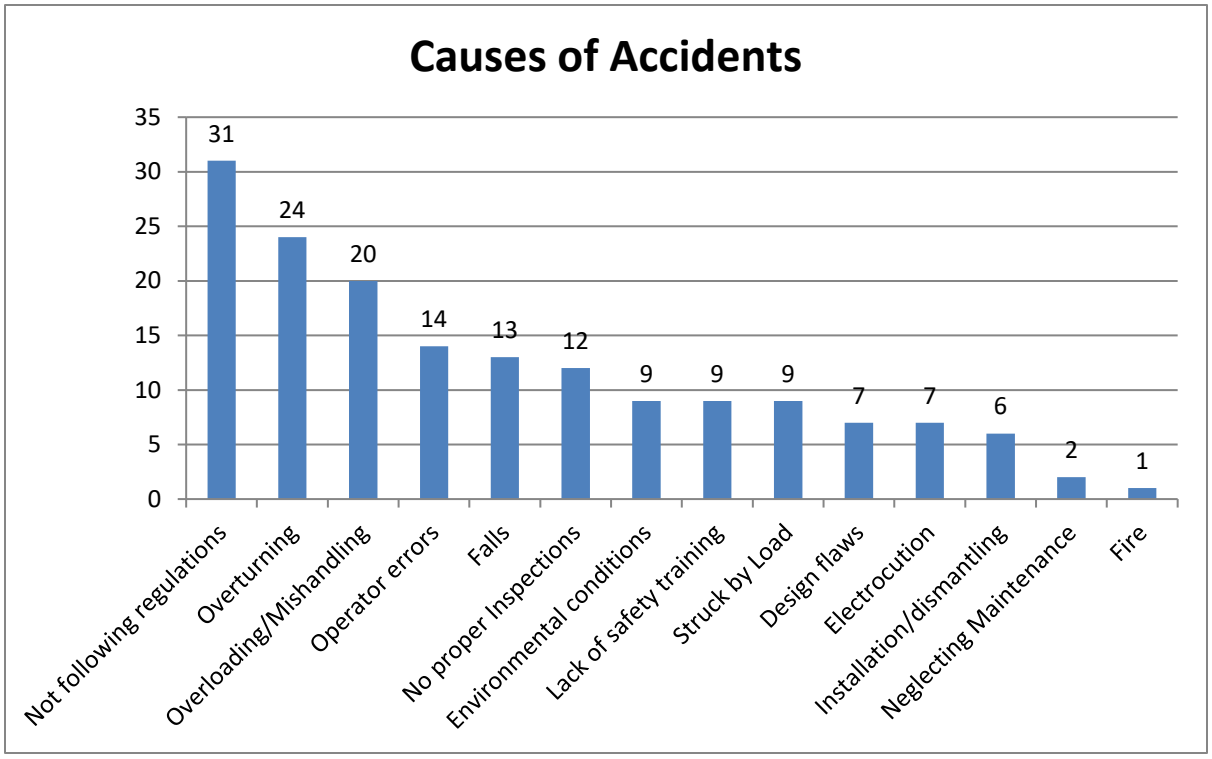

Figure 13: Accident Data

Table 7: Accident Data

Rank	Cause of Accident	Accident
1	Lack of regulation Enforcement or not following	31
2	Overturning of crane	24
3	Overloading or mishandling of load	20
4	Operator errors/mistakes	14
5	Falls (from heights)	13
6	Lack of (or) No proper Inspections	12
7	Struck by Load	9
7	Lack of safety training and licensing (personnel in and	9
7	Environmental conditions (Harsh weather like wind, etc.)	9
8	Structural Failure of crane due to Design flaws	7
8	Electrocution/contact with power lines	7
9	Crushed during installation/dismantling of tower cranes	6
10	Neglecting required Maintenance	2
11	Fire	1

The most common cause of crane accidents according to the respondents was Lack of regulations or not following the regulations which was also the cause of near misses. Hence, we can deduce that the top cause of crane incidents in KSA is due to Lack of Regulation Enforcement or not following them. The Human and Management errors are the main factors leading to high incident rate in the country. Around 90% of the respondents complained that safety wasn't given much importance even in big

government projects in KSA. The client allotted small budget to safety which forced the contractor to adopt lesser safe conditions or sometimes unsafe conditions on the site. This led to many accidents and near misses on site almost became a routine for them.

4.10.2.1 Importance Index for Accidents

When we observe the number of accidents with respect to grade of the company, we find that there are total of 161 accidents of which 34.16% are from grade 1, 34.16% from grade 2 and 31.67% from grade three. The data collected from survey shows high number accidents in grade 1 because they companies are 45.45% of the companies surveyed as compared to 34% of grade 2 and 20.45% of grade 3.

Therefore, dividing the number of accidents by the number of companies surveyed in the respective grades, we have 2.75 accidents per company in grade 1, 3.67 accidents per company in grade 2 and 5.67 accidents per company in grade 3. Hence it is evident that there are more accidents per company as we move from grade 1 to grade 3.

Figure 14 shows the relation between company grade and average accidents per company:

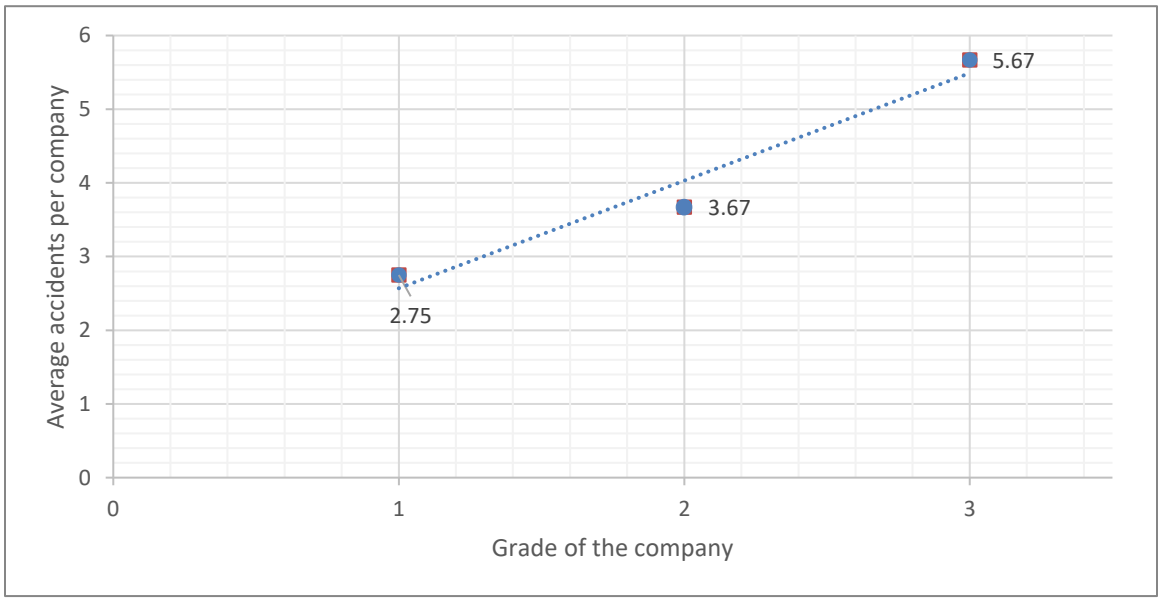

Figure 14: Company Grade vs Average Accidents per Company

From the graph, we can notice that as we move from grade 1 to grade 3, the number of accidents per company increases. This relates to the fact that companies in lower grade take more private projects and give negligible attention to safety on the site.

4.10.2.2 Discussion for the other leading causes

The subsequent prominent causes of accidents were overturning of crane, Overloading and Operator errors. Many of the respondents explained that these three causes were interlinked with one another. Many at times, the crane was used to lift weight beyond its critical load limit. The operators often think that lifting load a slightly beyond the critical load limit won't do any harm and finish the job sooner. Due to this attitude, the operator didn't even realize that the weight of the lifted load was increasing with subsequent lifting operations. Hence it led to accident on the site where the crane overturned. Many respondents chose to

include this type of near misses as operator errors which is evidently the second highest cause of near misses in crane operations.

The respondents explained that overturning of crane was also caused due to instability of soil conditions. In other words, the soil wasn't compacted properly or the mobile crane was used on unstable or unlevelled ground. Almost all accidents involved harming human lives but this type of accident, in addition, involved serious equipment and property damage (above SAR 100,000 in one response). Also, Overturning is the only factor that can result due to all categorization of causes i.e. Human error, Operational/Management error, Engineering error and Environmental Impact. Moreover, all the categories of causes of Crane Accidents are predominant in the country, top two being Human errors and Operational/Management errors.

4.11 People Affected in the Incidents

The respondents were asked about the people involved in the accident. Their number and condition (whether injured or death) was also asked. Figure 15 summarizes the responses:

Figure 15: People affected due to Accidents

We can observe that the Workers (Rigger, Laborers, Signalmen, etc.) have the highest rate of injury or death in crane accidents followed by crane operators then lastly the civilians. Therefore, the workers in and around crane operations are more vulnerable to crane accidents. One of the leading causes of near misses was Lack of safety training (personnel in and around crane operations). What this means is either there is no safety induction training for workers or that safety training given to personnel about crane equipment and operations isn't helpful to increase safety level on the work site. This leads them erring during work execution endangering their life and of those around them.

In addition, there were 55, 73 and 63 individuals affected (both Injured and Fatal) in Grade 1, 2 and 3 companies respectively. Again, to get a clear idea about average people affected, we should divide it by the number of companies the respective Grades.

We obtain 2.75, 4.86 and 7.8 individuals affected in Grade 1,2 and 3 respectively. Following is the graphical representation (Figure 16):

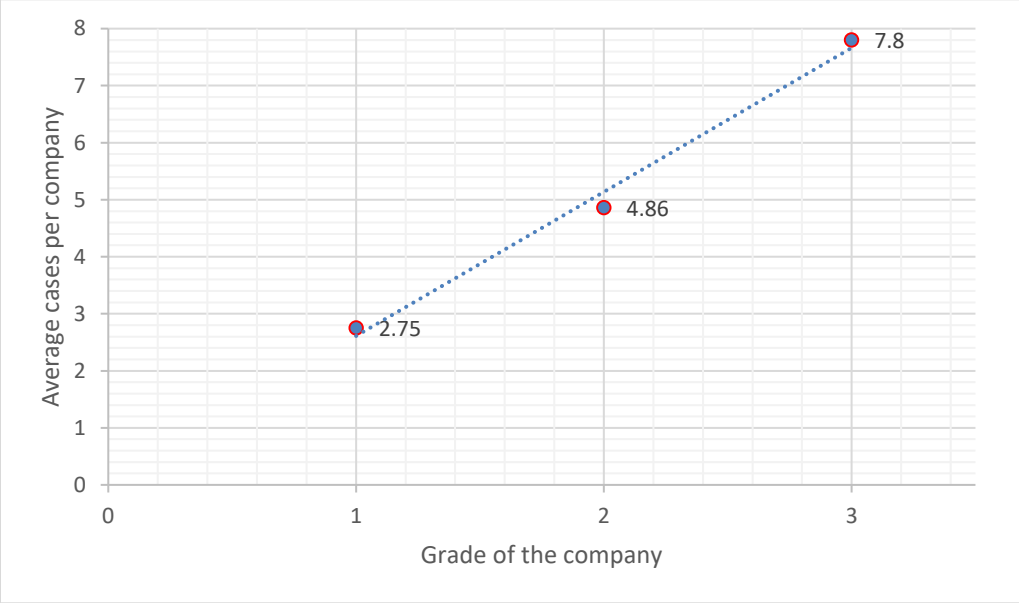

Figure 16: Company Grade vs Average Cases per Company

From the Trendline in the Graph (Figure 16), we can notice that the Number of Injuries and Fatalities per Company increases as we move from Grade 1 to Grade 3. This shows the critical level of Safety in especially Grade 3 companies which is affecting human lives. Every life is valuable, whether it be a worker, civilian or a manager.

One of the respondents from Grade 3 company mentioned a case where the worker was seriously injured which led to a deep cut in his abdomen. Adequate first aid wasn't

available on site which led to worsening of his health. He was rushed to the hospital after sometime. It caused temporary disability for him. Further, he came to the management to request for money for his recovery expenses. The management ignored his request and then he collected money from elsewhere to cover his expenses. This shows an example of poor safety culture in the organization. All the personnel from the client to senior management to workers have negligible value for safety. There is poor decision making and lack of clear direction at the management level. This leads to frequent occurrence of incidents, decreased worker morale, increased sickness rates, etc.

4.12 Q-Q Plots, ANOVA tests and Tukey's tests

In this section, the data from Near Misses, Accidents and Cases (Injury and Fatal) will be analyzed in SPSS and results will be discussed.

4.12.1 Q-Q Plots for Near Misses, Accidents and Cases

The Q-Q Plots for the above data were plotted in SPSS to check the deviation from the Normal Distribution:

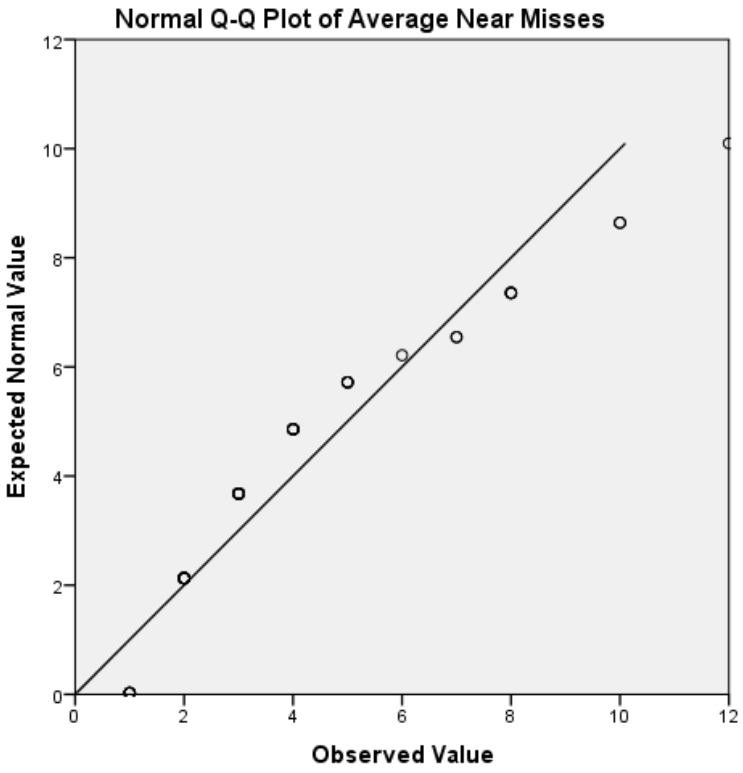

Figure 17: Q-Q Plot for Average Near Misses

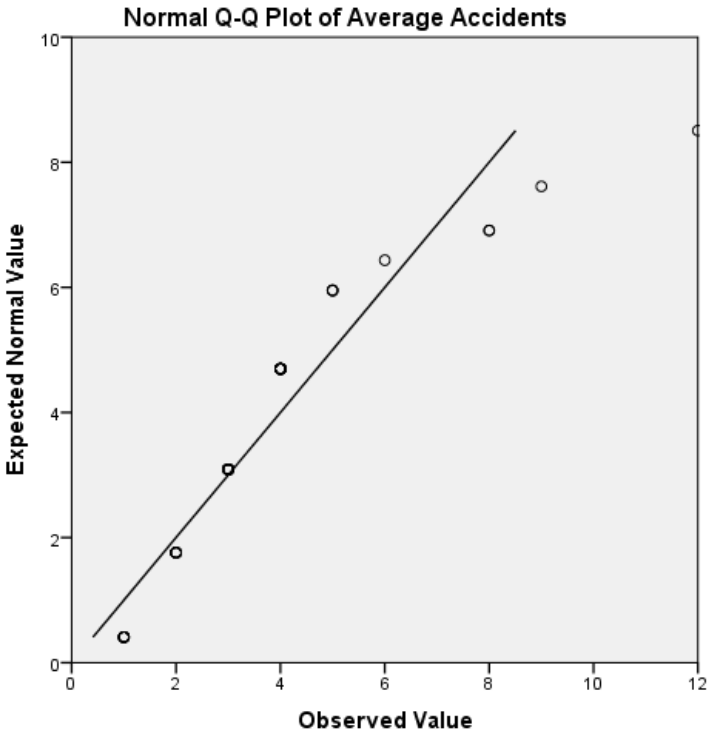

Figure 18: Q-Q Plot for Average Accidents

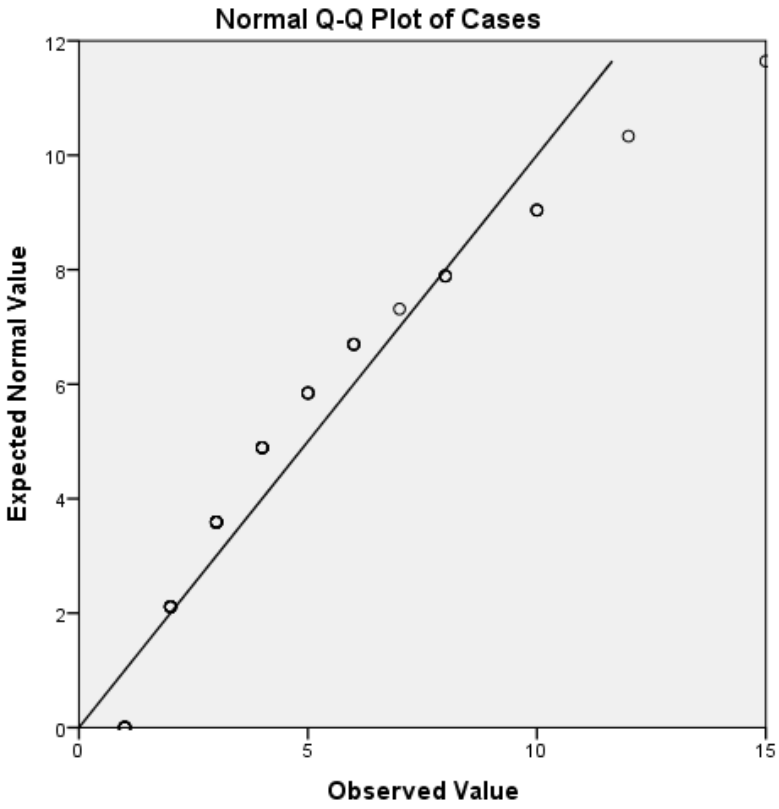

Figure 19: Q-Q Plot for Average Cases

All the three graphs (Figures 17,18 and 19) show that the data for near misses, accidents or cases is near to the expected normal value and show very less deviation. Hence, it can be safely assumed that data has a normal distribution. Thus, ANOVA test can be applied.

4.12.2 ANOVA test for Near Misses, Accidents and Cases

Table 8: ANOVA results from SPSS

ANOVA

		Sum of Squares	df	Mean Square	F	**Sig.**
Average Near Misses	Between Groups	110.840	2	55.420	10.620	**0.000192**
	Within Groups	213.956	41	5.218		
	Total	324.795	43			
Average Accidents	Between Groups	52.803	2	26.402	6.891	**0.0026**
	Within Groups	157.083	41	3.831		
	Total	209.886	43			
Cases	Between Groups	166.605	2	83.303	11.926	**0.000083**
	Within Groups	286.372	41	6.985		
	Total	452.977	43			

Table 8 shows the ANOVA results for Near Misses, Accidents and Cases for all the Grades. The p-value obtained was 0.000192 for Near misses, 0.0026 for Accidents and 0.000083 for Cases. Since all the values are less than α, the null hypothesis is rejected i.e. the group means for Grade 1, 2 and 3 are significantly different with respect to each other. Given that the test rejected the null hypothesis, Tukey's Test can be applied to further check significant difference between means of combinations of any two Grades.

4.12.3 Tukey's test for Near Misses, Accidents and Cases

Table 9: Tukey's test for pairwise comparisons (Results)

Multiple Comparisons

Tukey HSD

Dependent Variable	Company Grade (i)	Company Grade (j)	Mean Difference (i - j)	Std. Error	**Sig.**	95% Confidence Interval	
						Lower Bound	Upper Bound
Average Near Misses	Grade 1	Grade 2	-1.80000	.78027	**.066**	-3.6973	.0973
		Grade 3	-4.17778*	.91692	**.00013**	-6.4074	-1.9481
	Grade 2	Grade 1	1.80000	.78027	**.066**	-.0973	3.6973
		Grade 3	-2.37778*	.96318	**.046**	-4.7199	-.0357
	Grade 3	Grade 1	4.17778*	.91692	**.00013**	1.9481	6.4074
		Grade 2	2.37778*	.96318	**.046**	.0357	4.7199
Average Accidents	Grade 1	Grade 2	-.91667	.66857	**.365**	-2.5424	.7091
		Grade 3	-2.91667*	.78566	**.002**	-4.8271	-1.0062
	Grade 2	Grade 1	.91667	.66857	**.365**	-.7091	2.5424
		Grade 3	-2.00000	.82530	**.050**	-4.0068	.0068
	Grade 3	Grade 1	2.91667*	.78566	**.002**	1.0062	4.8271
		Grade 2	2.00000	.82530	**.050**	-.0068	4.0068
Cases	Grade 1	Grade 2	-2.11667	.90271	**.061**	-4.3117	.0784
		Grade 3	-5.13889*	1.06081	**.00005**	-7.7184	-2.5594
	Grade 2	Grade 1	2.11667	.90271	**.061**	-.0784	4.3117
		Grade 3	-3.02222*	1.11433	**.026**	-5.7319	-.3126
	Grade 3	Grade 1	5.13889*	1.06081	**.00005**	2.5594	7.7184
		Grade 2	3.02222*	1.11433	**.026**	.3126	5.7319

*. The mean difference is significant at the 0.05 level.

Table 9 shows the results for Tukey's test. The bold numbers show p-values obtained.

1. **Near Misses:** The null hypothesis is rejected for Grade 1 vs Grade 3 and Grade 2 vs Grade 3 (as p-value $\leq \alpha$) but retained for Grade 1 vs Grade 2 (as p-value $> \alpha$). We can infer that:
    - Average Near Misses for Grade 3 is significantly different from that of Grade 1 as well as of Grade 2;
    - Average Near Misses of Grade 1 and Grade 2 are not significantly different.
2. **Accidents:** The null hypothesis is rejected for Grade 1 vs Grade 3 and Grade 2 vs Grade 3 (as p-value $\leq \alpha$) but retained for Grade 1 vs Grade 2 (as p-value $> \alpha$). We can infer that:
    - Average Accidents for Grade 3 is significantly different from that of Grade 1 as well as of Grade 2;
    - Average Accidents of Grade 1 and Grade 2 are not significantly different.
3. **Cases (Both Injury and Fatal):** The null hypothesis is rejected for Grade 1 vs Grade 3 and Grade 2 vs Grade 3 (as p-value $\leq \alpha$) but retained for Grade 1 vs Grade 2 (as p-value $> \alpha$). We can infer that:
    - Average Near Misses for Grade 3 is significantly different from that of Grade 1 as well as of Grade 2;
    - Average Near Misses of Grade 1 and Grade 2 are not significantly different.

We can observe that in all three categories i.e. Near Misses, Accidents and Cases, there is no significant difference between Grade 1 and Grade 2 companies regarding Average

number of Near Misses, Accidents or Cases. Apparently, there is increase in the number of Average Incidents in Grade 2 companies when compared to Grade 1 companies but Tukey's test results show that they are not significantly different. This is possible because there are many Grade 2 companies which handle projects by big clients that follow safety like Aramco, Civil Defense, etc. But the size of their projects is not as large when compared to Grade 1. Other factors that might affect the lower but sufficient level of safety in Grade 2 companies are Company Budget, Revenue and Cash Control, Experience of Skill persons in the company, Company Management, Safety Culture, etc. Another major observation is that Grade 3 Incidents are significantly different from Grade 1 as well as Grade 2 companies. This is also evident from the comparison of Average number of Incidents between the Grades i.e. Grade 3 Averages are very high when compared to the other two. The reasons for this significant difference were tendency to follow regulations, standard enforcement by client, Lack of importance to safety, etc. which were highlighted in the previous sections above.

4.13 Type of Crane in the Incidents

Figure 20 is the graphical representation of the cranes involved in the accidents experienced by the respondents:

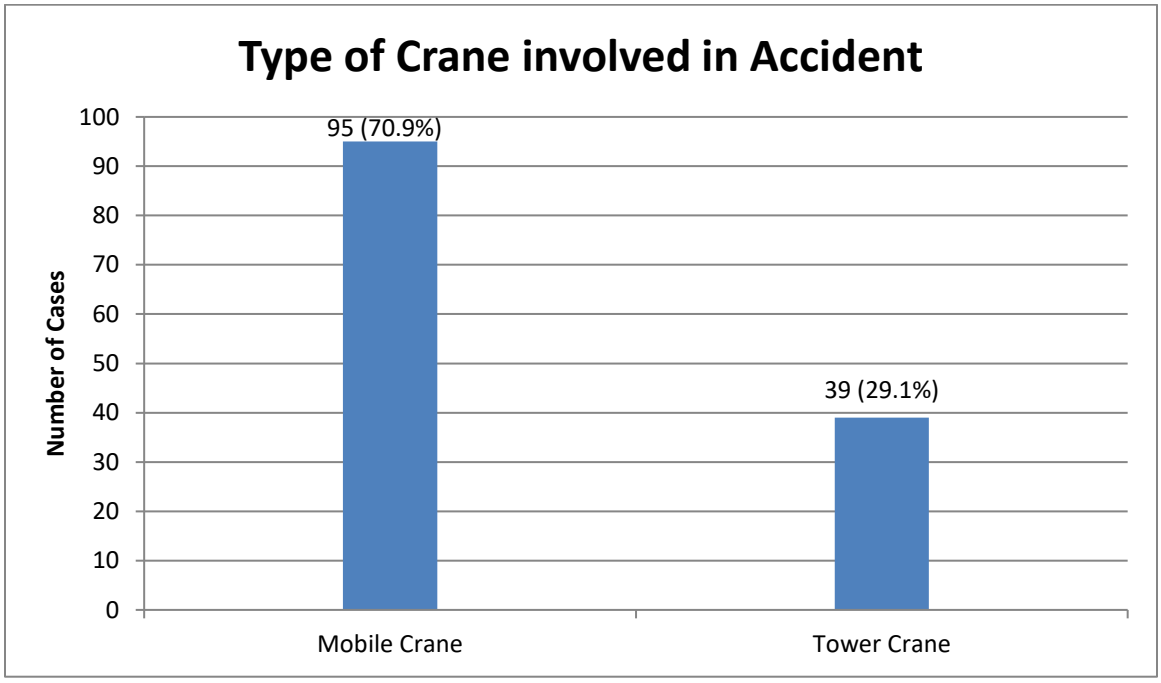

Figure 20: Types of Cranes in Accidents

As we can observe most of the accidents consist of mobile cranes. But we also must consider the fact that about 70% of the cranes used in Saudi Arabia are mobile cranes hence increasing their probability of being involved in an accident.

One interesting thing pointed out by the respondents about mobile cranes was that there were many accidents that occurred due to overturning of crane due to unstable soil conditions. This cause of accident was the second most prominent cause of accidents hence increasing the number of mobile cranes involved in the accident.

4.14 Certification and Licensing

The respondents were asked about the certification of cranes and licensing of crane operators. Figure 21 shows the responses:

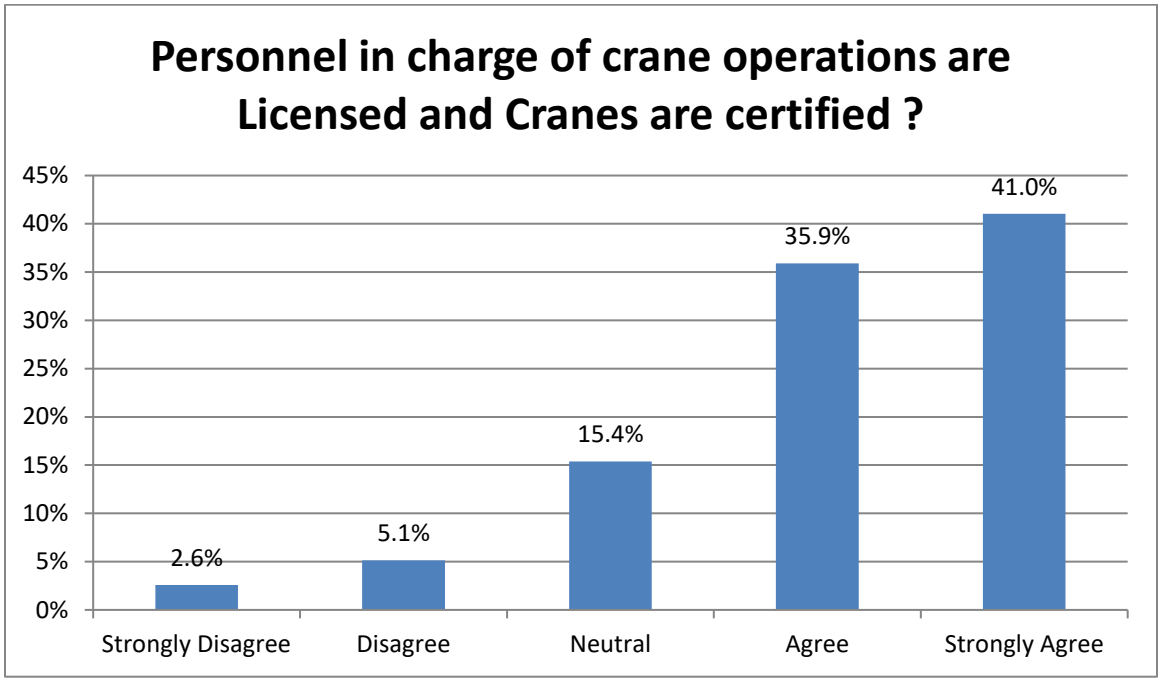

Figure 21: Crane Certification and Operator Licensing

About 77% of the respondents agree to the fact that Personnel in charge of crane operations in Saudi Arabia are Licensed and Cranes, certified. However, about only 7.5% of the respondents disagreed about it. Further, 15.4% of them were neutral. When asked their response, they said that all clients in government sector and some of the clients in private sector strictly required the crane and its safety to be inspected and certified and operators to be licensed. But most of the clients in private sector overlooked this requirement. The operator was hired merely based on his experience. In other words, the licensing and certification is commonly followed in the public sector and rarely adhered to in the private sector.

Other main reason that most of the respondents agreed was that operator licensing and crane certification are mandatory requirements in all government organizations in Saudi Arabia. Hence companies hire licensed crane operators only [ARAMCO approved operators are preferred]. Further, cranes are certified by third party companies which are registered with the government. They provide approval certificate after detailed inspection. This certification is mandatory for the company to acquire proceeding work execution. Most of the companies have dealt with or are currently dealing with different government organizations hence a high percentage of them agreeing with the statement. This is a satisfactory feature about Saudi Arabian construction industry that crane safety requirements are met regarding this issue.

4.15 Respondent's opinion about the Causes of Accidents

The respondents were then asked to rate the causes of crane accidents in Saudi Arabia on the scale of 1-4.

To better understand the overall significance of each cause, their Importance Index was tabulated and is presented graphically below in figure 22:

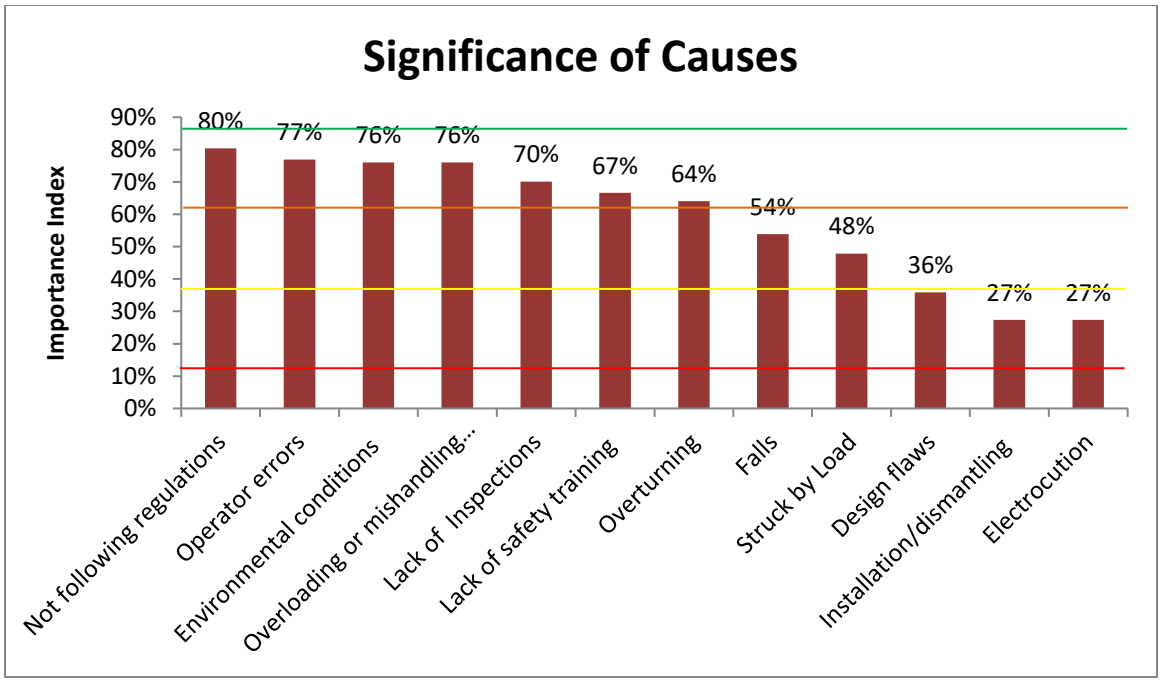

Figure 22: Importance Index for Various Causes

Table 10: Importance Index classification for causes

Importance Index	Classification
0–<12.5%	Not significant
12.5–<37.5%	Low significance
37.5–<62.5%	Significant
62.5–<87.5%	High significance
87.5–100%	Very high significance

Table 11: Ranking of causes as per Imp. Index

Rank	Cause of Accident	Importance Index
1	Lack of regulations or not following regulations	80%
2	Operator errors/mistakes	77%
3	Overloading or mishandling of load	76%
4	Environmental conditions (Harsh weather like wind, etc.)	76%
5	Lack of (or) No proper Inspections	70%
6	Lack of safety training and licensing (personnel in and around crane operations)	67%
7	Overturning of crane	64%
8	Falls (from heights)	54%
9	Struck by Load	48%
10	Structural Failure of crane due to Design flaws	36%
11	Electrocution/contact with power lines	27%
12	Crushed during installation/dismantling of tower cranes	27%

4.15.1 “High Significance”

We can observe that 7 factors falling in the category of “High Significance” (Tables 10 and 11). These are:

1. Lack of regulations or not following regulations
2. Operator errors/mistakes
3. Overloading or mishandling of load
4. Environmental conditions (Harsh weather like wind, etc.)
5. Lack of (or) No proper Inspections
6. Lack of safety training and licensing (personnel in and around crane operations)
7. Overturning of crane

In the opinion of the respondents, these causes of accidents are highly significant and often lead to serious accidents. Also, the significance of occurrence of these causes conforms with the incident data obtained above regarding near misses and accidents These causes are associated with high Human and Operational/Management errors. Hence, we can understand the fact that Human and Operation/Management are two weak areas of Safety Management in the Saudi Arabian Construction Industry. These areas should be given special concern to improve the overall level of Safety in Saudi Arabia.

4.15.2 “Significant”

The next causes, which are of “Significant” level, are:

8. Falls (from heights)
9. Struck by Load

These causes have lesser significance than those above but sometimes lead to accidents.

4.15.3 “Very low Significance”

10. Structural Failure of crane due to Design flaws

11. Electrocution/contact with power lines

12. Crushed during installation/dismantling of tower cranes

These causes have very low significance when compared to those above. The respondents said that these causes are not significant in Saudi Arabia and have rare occurrences. Moreover, we can observe that these causes fall under the category of Engineering Errors. Hence, we understand that Engineering Factors related to Crane Safety are strong areas in the Saudi Arabian construction industry.

4.16 Comparison of the Safety Level, Accident level and Company Grade

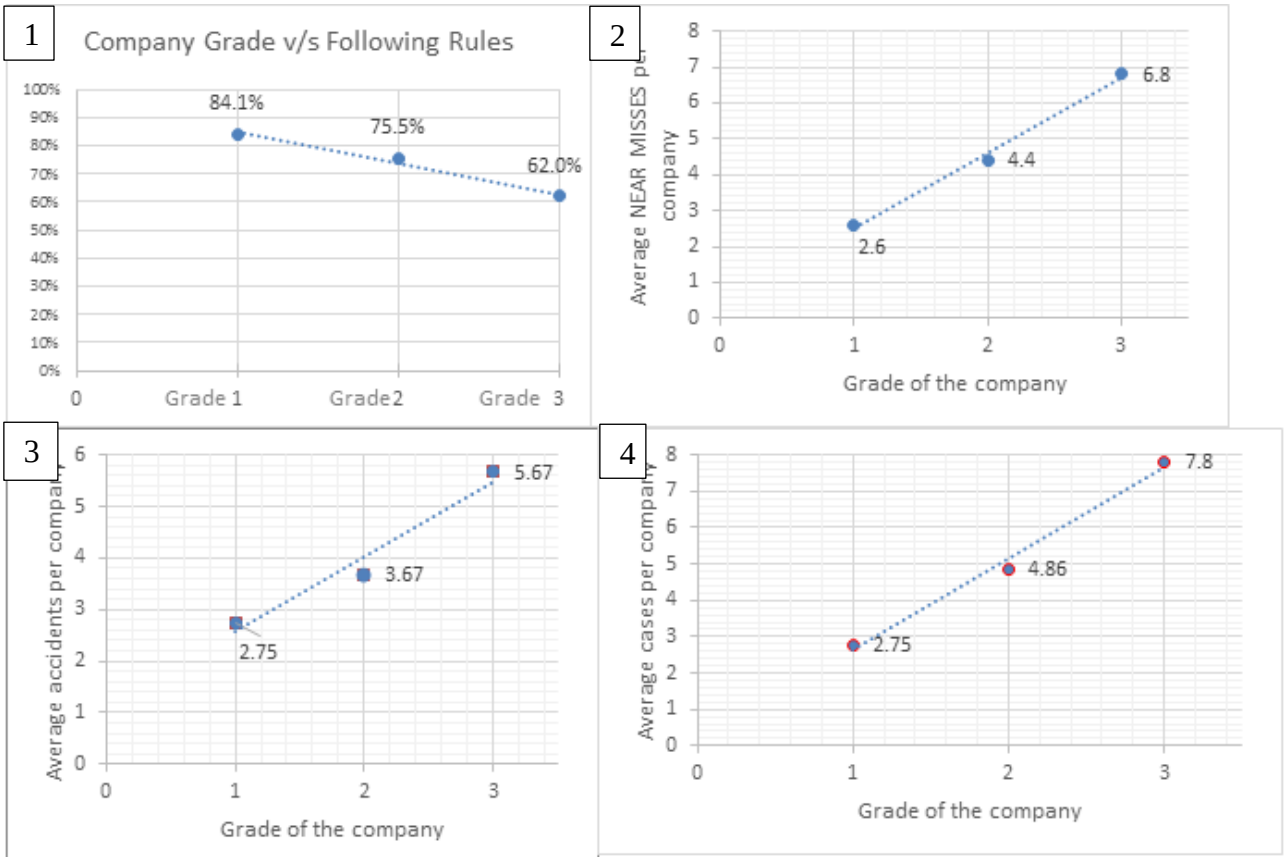

Figure 23: Comparison of Four Graphs

The four graphs shown in figure 23 were obtained in previous sections above. Following is the summary:

1. Graph between Company Grade and Following Rules: This graph shows the decreasing tendency to follow safety regulations as we move from Grade 1 to Grade 3
2. Graph between Company Grade and Average Number of Cases: This graph depicts the increasing Cases per company as we move from Grade 1 to Grade 3.

3. Graph between Company Grade and Average Number of Near misses: This graph depicts the increasing Near Misses per company as we move from Grade 1 to Grade 3.
4. Graph between Company Grade and Average Number of Accidents: This graph depicts the increasing Accidents per company as we move from Grade 1 to Grade 3.

When we compare the Graphs 2,3 and 4, we observe that Near misses, Accidents and Cases increase as we move from Grade 1 to Grade 3. In addition, the two variables in any of these graphs have very high correlation coefficient. There is an increase in the injuries and fatalities along with the increasing occurrence of Incidents in Lower Grade companies.

Now, in graph 1 we see decreasing tendency of following regulations in Lower grade companies. When we put these two facts into the picture, we observe that they conform with each other. This means that as we move from Grade 1 to Grade 2 to Grade 3, the decrease in dedication to follow the safety rules and regulations leads to higher number of accidents Crane Incidents which in turn leads to higher injuries and deaths in the construction Industry. Hence, smaller companies have very low safety level in Saudi Arabia.

This agrees with previous studies conducted by Jannadi & Alsudairi (1995), Jannadi & Assaf (1998) and Jannadi & Al-Utaibi (2004). These studies showed that the safety level increases as the project size increases and as the safety level increases, accident rate decreases. This is exactly what we have deduced in the graphs above.

4.17 Safety Equipment, Procedures and Personnel

The respondents were asked about the safety equipment and procedures implemented in Saudi Arabia on the scale of 1 to 4. The data was then summarized in the form of Importance Index and is shown below in figure 24.

4.17.1 Safety Equipment:

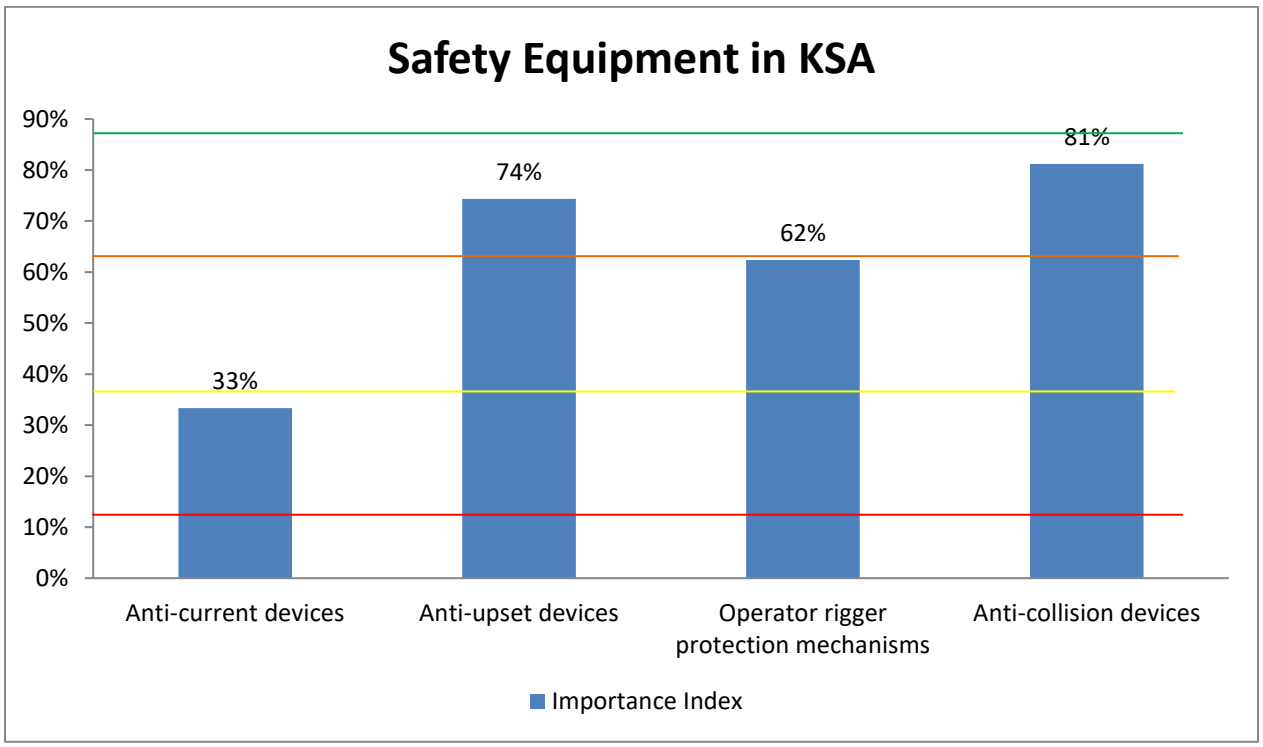

Figure 24: Importance Index for Safety Equipment

Table 12: Importance Index classification for Safety Equipment

Importance Index	Classification
0–<12.5%	Not Used
12.5–<37.5%	Rarely used
37.5–<62.5%	Sometimes Used
62.5–<87.5%	Often Used
87.5–100%	Always Used

We can notice that Anti-upset devices and Anti-collision devices are often used by the companies in Saudi Arabia. Further, Operator Rigger Protection Mechanisms, which are a safety precaution for crane operators, are only sometimes used.

Anti-Current devices are rarely used for crane safety in Saudi Arabia. The respondents said that they hardly encountered overhead power lines in the proximity of cranes since most of the electric power lines are underground in Saudi Arabia. In addition, when we compare the incidents due to Electrocution in Saudi Arabia with similar Incidents in other countries, the Incident occurrence is very low. Contrastingly, many studies showed that Electrocution was one of the top causes of Crane Accidents in other countries. However, some companies worked with or usually work with clients in Electrical Works (E.g. SCECO). They are using cranes for selective works where the crane is likely to encounter electricity. E.g. Excavation work where underground cables are exposed and require crane for installation and repair functions, Cranes being used near transformers, etc.

Despite having such nature of work, they responded that they weren't using Anti- Current Devices as a safety precaution.

4.17.2 Safety Procedures:

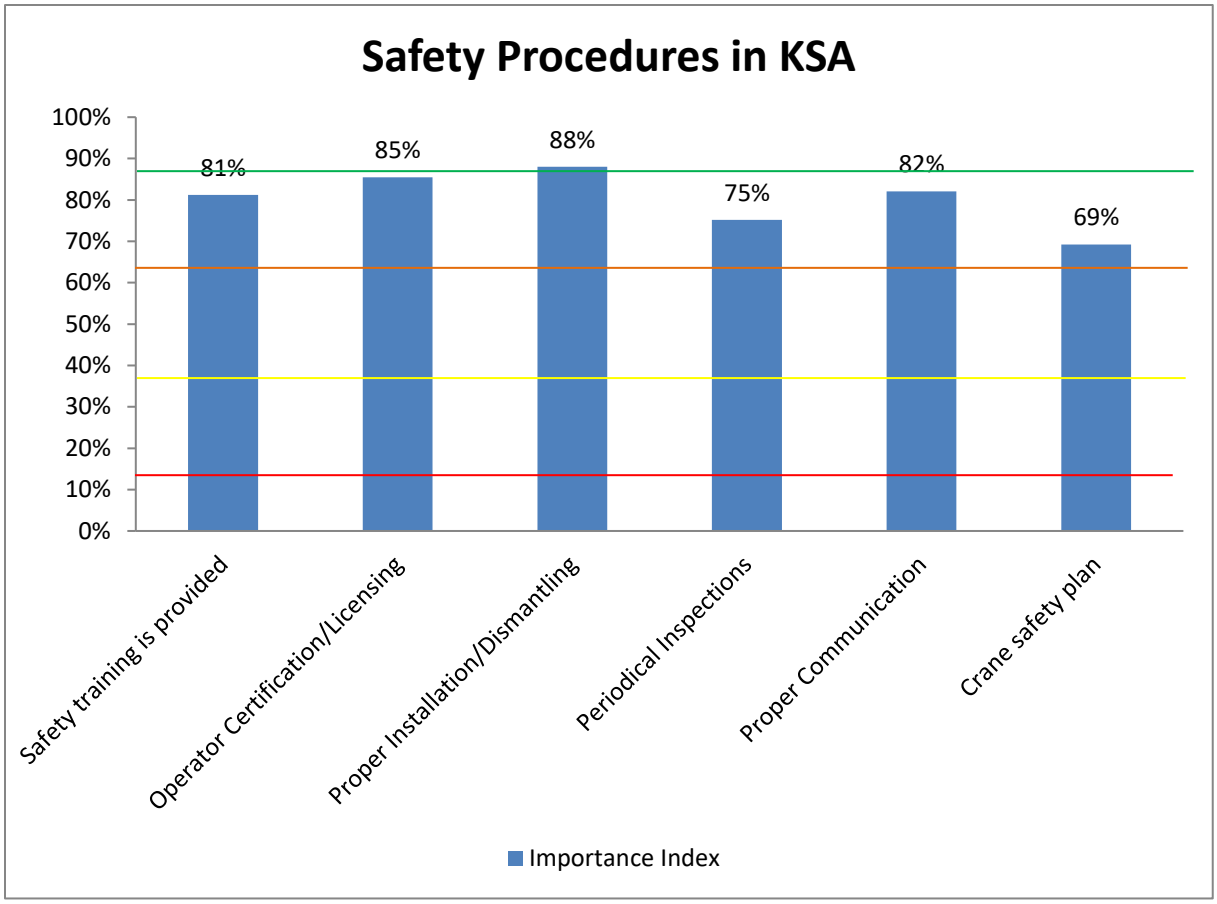

Figure 25: Importance Index for Safety Procedures

Table 13: Importance Index classification for Safety Procedures

Importance Index	Classification
0–<12.5%	Not Followed
12.5–<37.5%	Rarely Followed
37.5–<62.5%	Sometimes Followed
62.5–<87.5%	Often Followed
87.5–100%	Always Followed

Of all the safety procedures followed to prevent accidents due to cranes, Safe Installation and Dismantling of Tower cranes was Always Followed. The respondents mentioned that there are specialized subcontractors for this work and they take all safety precautions while installing and dismantling crane. Moreover, after the complete assembly of the Tower crane, cranes are thoroughly inspected and certified for use. Almost all respondents using tower cranes agreed on this matter. This corresponds with the fact that the installation and dismantling of Tower Crane is has low occurrence in the near misses and accidents in the previous graphs.

All the other safety procedures fall in the category of being "Often Followed". The respondents indicated that all safety procedures are followed (for the record) i.e. for the administrative requirements to record officially and show that procedures are being followed. But as we can notice, in actuality, rules and regulations are not being adhered to. In addition, procedures like safety training were not effective as it didn't help the workers completely understand the hazards and risks of cranes at work sites which led them to be a victim of dangerous accidents.

These facts can be summarized as follows:

- The management on site merely make it look that the regulations are adopted but in reality, they are not followed the way they are supposed to be followed.
- Safety training has very less effect on the workers i.e. the workers don't understand consequences for the hazards and risks at the workplace.

o Proper planning of crane actives is not accomplished prior to the operations.

4.18 Personnel responsible for Crane Accidents:

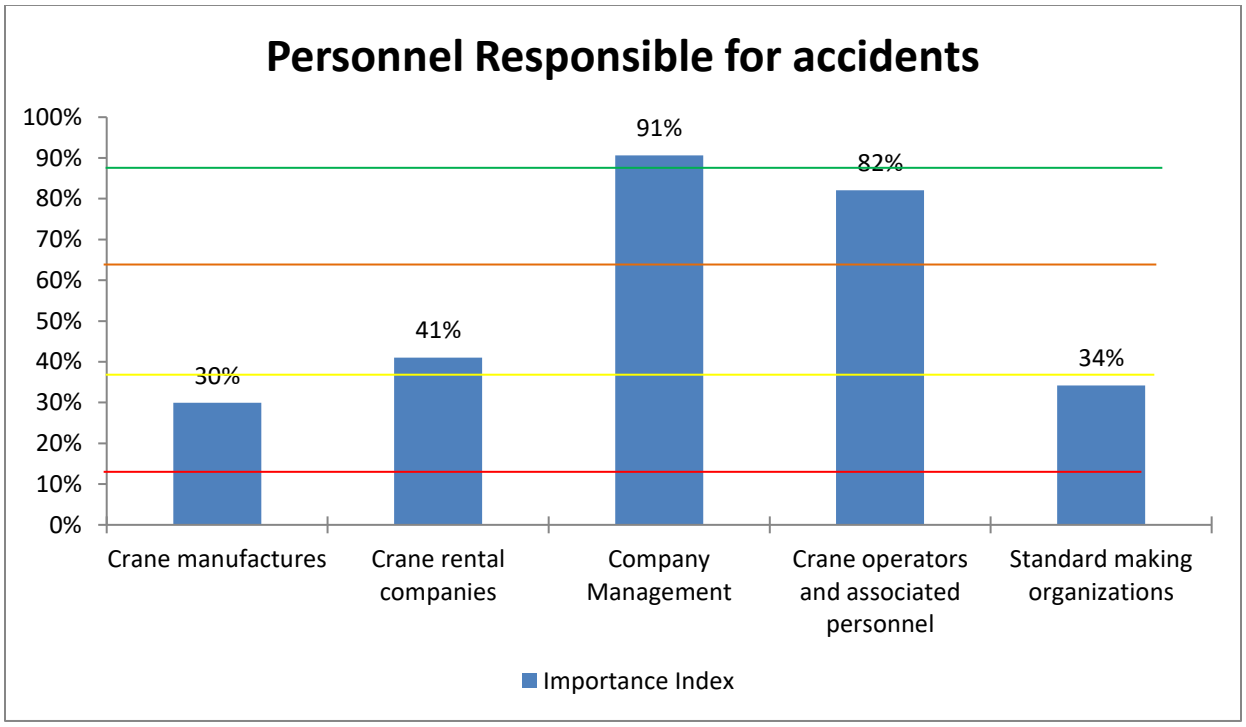

Figure 26: Importance Index for Safety Responsibility

Table 14: Importance Index classification for Safety Responsibility

Importance Index	Classification
0–<12.5%	Not Responsible
12.5–<37.5%	Rarely Responsible
37.5–<62.5%	Sometimes Responsible
62.5–<87.5%	Often Responsible
87.5–100%	Always Responsible

The Company Management having an Importance Index rating of 91% explains the opinion of the respondents that they are Always Responsible for Crane accidents. Some of the respondents complained that the Company Management didn't give importance to crane safety and didn't allocate sufficient resources for safety management of cranes.

The Crane operators and associated personnel are "Often responsible" for crane accidents as ultimately its upon them to take adequate safety precautions and follow all safety rules and regulations to their best ability. They should be competent enough to work safely with (and around) cranes and to know the hazards and risks of crane and its operations.

The respondents have the opinion that the Crane rental companies are "Sometimes Responsible" and Crane manufacturers and Standard making Organizations are "Rarely Responsible" for crane accidents in KSA.

It is important here to note that in the analysis of Incident data, we obtained the categories of causes of major concern in Saudi Arabia as obtained above were Human, Operational and Management errors. The opinion of the respondents regarding responsible people for Crane Safety shows that Management and Human error are in fact areas of major concern. This confirms our conclusion that these areas should be given special consideration to improve the overall level of Safety in Saudi Arabia.

4.19 Comments and Suggestions from Respondents

- There should be an independent body Agency, Organization or a society for crane safety, operation and crane follow-up in KSA, due to its extent of usage in industries and others. A crane organization can monitor all developments when it comes to use of cranes and continuous updates on international safety, design, operation, Safe Working Loads (SWL), etc. to keep up with the worldwide industry.

  Crane is very powerful and essential to complete any job and also a very expensive tool. Requirements on operation are dependent on many factors that range from manufacturing, operation, rigging, environment, weather, etc.
- Not regularly inspecting crane is one of the serious mistakes in the construction industry. Cranes are operated without any inspection may endanger the life of everyone on site. Periodical inspections through certified inspectors should be the norm of crane working. There are some lesser known but important inspections. For e.g.:
  - Inspecting soil/ground conditions and compacting before operations
  - Hook pop mark inspection
  - Cable wire break test.
- KSA shall form a separate governing body focusing on crane safety or at least safety in general. All rules and regulations shall be adopted from these standards to be enforced in KSA.
- Only large organizations are following safety standards like Aramco, Civil Defense and Royal Commission, others only follow basic safety or no safety.
- Periodical training with important standard updates must be provided to workers.

- Value of a human life is underrated in KSA
- Safety should be a separate bidding item during bidding.
- Aramco has the best safety standard in Saudi Arabia and is often followed by their contractors
- It is often a practice in KSA to carry out inspections but neglect maintenance.

Following image (Figure 27) is the word bubble of the comments which shows the frequently used words by the respondents:

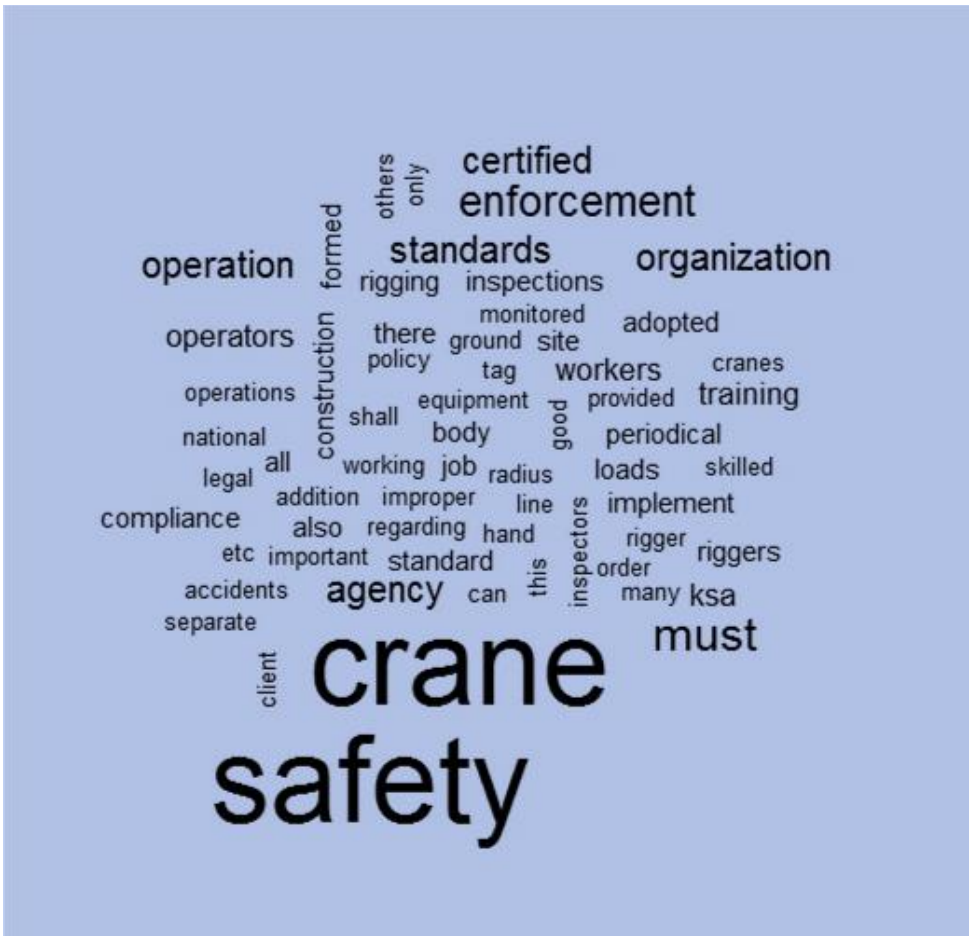

Figure 27: Word bubble for Frequent words used in Comments

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

Cranes are the backbone of construction industry and are one of the significant components for execution of construction work. Nevertheless, they have caused up to one-third of the deaths in the construction industry. Saudi Arabia is no exception to this and the problem of increasing Crane Accidents had to be addressed. This research was performed to understand that problem by thoroughly studying the incident data in the past five years from various construction companies. Various crane incidents and their causes were discussed and their frequency was also observed. This revealed the weak areas of Safety in Saudi Arabia i.e. Operational/Management Errors and Human Errors.

This study was divided into five chapters. Chapter 1 introduced the research, its aim and objectives and its scope.

In chapter 2, crane as an equipment was discussed including various Crane Accidents around the world. Different causes of Crane Accidents were collected and categorized into four: Engineering Errors, Human Errors, Operational/Management Errors and Environmental Impact.

Chapter 3 dealt with Methodology adopted in this research to acquire data which was questionnaire survey method with Personal Interviews.

Chapter 4 presented the most important part of the research i.e. different tools and techniques used to analyze the data obtained. Analyzed information was presented under various sections and the results were discussed. The results allowed us to gain insight on the Crane Accident in the Saudi Arabian Construction Industry, hence achieving the aim of the research.

5.2 Conclusions

A thorough analysis and discussion of the information obtained from various companies involved in building construction have led us to gain a good understanding of the Crane accidents in the Saudi Arabian construction Industry. Human factors related to safety and Management of the company are two subjects that should be given significant consideration to eliminate problems associated with the construction industry in K.S.A. Further, the most prevalent causes of Crane accident in Saudi Arabia like Lack of regulation enforcement or Not Following Regulations, Operator errors Overloading or Mishandling of Load, Overturning of Crane, Lack of Inspections, etc. show that Human error and Operational/Management errors have a high impact on Crane Safety. However, Incidents due to Engineering Error have low occurrence in the country. Also, it was found that Workers in or around Crane Operations are most vulnerable people followed by crane operators when it comes to crane Accidents.

The Client plays a major role for implementing Safety in Construction Industry. But there is no specific Ministry, Organization, Agency, etc. which enforces standards of safety

over all in KSA. This Agency should overlook that an adequate level of safety standard enforced over the client with respect to the size of the project handled by them. This is a major issue also put forth by the respondents which needs to be solved.

Preventive measures in the form of Safety Equipment (Anti-Upset Devices, Anti-Collision Devices, etc.) and Safety Procedures (Safety Training, Periodical Inspection, etc.) are often adopted. However, Incidents continue to take place despite the fact. These preventive measures have very little effect on Crane Incident prevention.

5.3 Recommendations

The following Recommendations will be helpful to prevent future accidents, save loss of lives and property and enhance the overall Safety level in Saudi Arabia with respect to cranes:

- It is recommended the Government of Saudi Arabia should form an independent body, Agency, Organization or Society that focusses on Crane Safety or Safety in general. It can monitor all developments when it comes use of cranes and continuous updates on international safety, design, operation, Safe Working Loads (SWL), etc. to keep up with the worldwide industry.
- Safety Training should be provided not just for the sake of Workers and Operators merely attending it but to make them understand the hazards of the workplace and the risks associated with handling Crane equipment.
- Periodical inspections should be performed for all crane parts (including hooks, cables, etc.) to ensure safe working of crane. It should be carried out by specialists. Any discrepancy detected must be rectified immediately and must not be neglected.
- Load chart for crane must be adhered to. Load shouldn’t be lifted beyond the limit mentioned in the load chart.

- Ground conditions must be surveyed and inspected in order to find its stability and suitability for crane operation.

- The safety of Workers in and around crane operations must be further investigated to attain a safer workplace for workers and reduce the number of incidents.

- The cases of accidents are more in lower grade companies. Hence projects of such small-scale companies must be periodically scrutinized by the government authorities to ensure their level of competency in safety and also before assigning them a higher grade.

5.4 Recommendations for Future Research

- An extensive Research can be done in the cities in other provinces in Saudi Arabia like Riyadh, Jeddah, Makkah, Yanbu, Jizan, etc. these future researches can lead to a complete and overall understanding of the causes of crane accidents in Saudi Arabian construction industry.
- Saudi Arabia is on the verge of increasing safety on all work sites by enforcing strict rules and regulations especially for companies dealing with cranes. It has become obligatory for Various personnel at managerial level in the company to gain additional knowledge about the safety standards by taking classes for OSHA, NEBOSH, IOSH, etc. at various institutes. A research like this one can be conducted sometime in the future to discover the differences between the number of incidents, their causes, standards, etc. hypothesis testing method can be used to compare the data obtained with the data in this research to establish conclusions about the changes found, if any.

- Research can also be conducted on the different type of contractors that use cranes like Industrial contractors of varying grade levels.

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APPENDIX - Survey Questionnaire

Section 1 – General information about company and respondent

This section collects basic information needed to identify the various responses received.
ALL INFORMATION WILL BE KEPT SECURELY AND WILL REMAIN CONFIDENTIAL.

Demographic Information

1. **Company Name (Optional)_____**
2. **Your position (Please tick the option (✓)**
    a. **Manager (Project/Construction/ Safety)** **( )**
    b. **Engineer(Project/Site/Safety)** **( )**
    c. **Safety Supervisor** **( )**
    d. **Crane operator** **( )**
    e. **Others, please specify_____**
3. **Years of Experience**
    a. **Less than 5 years** **( )**
    b. **Between 5 and 10 years** **( )**
    c. **11-15 years** **( )**
    d. **16-20 years** **( )**
    e. **Above 20 years** **( )**

Section 2 – Information regarding Cranes and Crane safety

4. **On a scale of 1-4, how would you rate the usage of following type of cranes on construction sites in Kingdom of Saudi Arabia? (Please tick the option (✓)**

(1 –Not used at all; 2- Rarely Used; 3- Sometimes used; 4- Mostly used)

Type of crane	**1**	**2**	**3**	**4**
Mobile crane				
Tower crane				
Other (Bridge crane/Container crane, etc.): _____				

5. When comparing Mobile Crane and Tower crane, which one is more used on construction sites in Kingdom of Saudi Arabia?
(Please tick the option (✓)

- **a. Mobile Crane ( )**
- **b. Tower Crane ( )**

6. Which agency or organization do you think is enforcing or implementing the safety standards in K.S.A?

Answer: _____ *(E.g. Royal Commission, Saudi Aramco, Civil Defense, SASO, No particular organization etc.)*

7. **Which safety standard do you think is mostly followed in K.S.A?**

- **a. OSHA (***Occupational Safety and Health Administration***) ( )**
- **b. NEBOSH (***National Examination Board in Occupational Safety and Health***) ( )**
- **c. IOSH (***Institution of Occupational Safety and Health***) ( )**
- **d. Self-made company safety standards ( )**
- **e. Other _____ ( )**

8. **In your opinion, are the above safety standards followed in construction projects? (on a scale of 1-4)**
   (1 –Never followed; 2- Rarely followed; 3- Sometimes followed; 4- Often followed)

1	2	3	4

9. **Cause of the <u>Near misses or Accident</u> you may have encountered or heard about during your experience in K.S.A. (Please tick the option (✓). If more than one near miss or accident, kindly specify the number in the box)**

Cause of accident	Near misses	Accident
Overturning of crane		
Design flaws		
Overloading or mishandling of load		
Operator errors/mistakes		
Electrocution/contact with power lines		

Struck by Load		
Falls (from heights)		
Crushed during installation/dismantling of tower cranes		
Lack of safety training and licensing (personnel in and around crane operations)		
Environmental conditions (Harsh weather like wind, etc.)		
Lack of enforcing regulations or not following regulations		
Lack of (or) No proper Inspections		
Other (Please specify): _____ _____		

10. People involved in the near misses or accidents:

People	Select (✓)	Number Fatal	Number Injured	Total number
Crane operator				
Workers (Rigger, Laborers, Signalmen)				
Non-workers(Civilians)				
Other:				

11. Type of crane involved in the near misses or accidents:

Type of crane	Select	Number
Mobile crane		
Tower crane		
Other (Bridge crane/Container crane, etc.):		

12. On a Scale of 1-5, how would you rate the following statement:

"Personnel in charge of crane operations in Saudi Arabia are <u>Licensed or certified</u>"

1 – Strongly disagree; 2- Disagree; 3- Neutral; 4- Agree; 5 – Strongly agree

1	2	3	4	5

13. In your opinion, what do you think are the major <u>Causes of crane accidents in Saudi Arabia?</u>

Please rate the following <u>causes</u> on the scale of 1-4 (your opinion)

(1–Not at all Significant; 2- Rarely Significant; 3- Moderately Significant; 4- Highly Significant)

Cause of accident	**1**	**2**	**3**	**4**
Overturning of crane				
Design flaws				
Overloading or mishandling of load				
Operator errors/mistakes				
Electrocution/contact with power lines				
Struck by Load				
Falls (from heights)				
Crushed during installation/dismantling of tower cranes				
Lack of safety training and licensing (personnel in and around crane operations)				
Environmental conditions (Harsh weather like high winds, etc.)				

Lack of enforcing regulations or not following regulations				
Lack of or No Proper Inspections				
Other (Please specify): _____ _____				

14. In your opinion, how well do you think the following <u>safety measures</u> are implemented in K.S.A.? Please rate the following on the scale of 1-4 (1–Never used; 2- Rarely Used; 3- Sometimes used; 4- Often used)

Safety/Prevention Measures	**1**	**2**	**3**	**4**
<u>Crane safety equipment</u>				
Anti-current devices: Used to prevent accidents due to electrocution (Insulated lines or links/Insulating Barriers/ Proximity current detectors)				
Anti-upset devices: Used to prevent accidents due to overturning and adverse weather conditions like high winds				

Operator rigger protection mechanisms: Used to prevent injury to workers mainly operator. E.g. Cab reinforcement (both body and glass)				
Anti-collision devices: Used to prevent collision of cranes and other vehicles like aircrafts				
Crane Safety Procedures				
Safety training is provided to all personnel in and around crane operations (Operator, workers, etc.)				
Operator Certification/Licensing				
Proper Installation/Dismantling of crane				
Periodical Inspections				
Proper Communication: Hand signals, electrical and radio communications between different crane operation personnel				
Preparation, execution and monitoring of Crane safety plan				
Other safety measure 1 (Please specify):_____ _____				

Other safety measure 2 (Please specify):_____ _____				

15. In your opinion, how responsible are the following personnel <u>for crane accidents in Saudi Arabia?</u>

Please rate the following <u>personnel</u> on the scale of 1-4,

(1–Not responsible; 2- Less responsible; 3- Sometimes responsible; 4- Highly responsible)

<u>Personnel responsible for crane accidents in K.S.A.</u>	**1**	**2**	**3**	**4**
Crane manufactures (Adequate designing according to standards)				
Crane rental companies (providing standard equipment and maintenance)				
Company Management (in following safety regulations)				
Crane operators and associated personnel (riggers, signalmen, etc.)				
Standard making organizations/agencies in Saudi Arabia				

16. **Your personal / additional opinion about "Crane Safety in Saudi Arabia" or Your opinion on this Research:**

End of Questionnaire

☺ Thank You ☺

Vitae

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